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COMMAND and CONTROL

The Literature and Commentaries

Frank M. Snyder

NATIONAL DEFENSE UNIVERSITY

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Contents

Preface

This publication represents an effort by teachers and researchers at the Naval War College, Harvard University, and the Institute for National Strategic Studies to develop a practical textbook on command and control for those military officers and civilian official who are preparing to meet the special challenges of leadership in the years ahead. It recognizes the traditional, time-honored functions of command, explains more recent developments in the process of command and control, and examines both the useful capability and the perhaps imperfectly understood limitations of modern communications and computer systems.

We have all progressed from a world in which global strategies were paramount to one in which regional strategies and joint, combined, and coalitional operations have become the norm. In this new world, the military may be increasingly called upon to assume more noncombat roles and peacekeeping missions. The challenges to leadership, to command and control, grow more complex each year, as does the technology supporting the commander. But the balance between how individual commanders operate and how the C4 system itself affects their operations must be constantly readdressed and refined. This collection of readings and commentary intends to do just that.

All who have contributed to the writing and publishing of this pioneering text are united in the desire to make it the most serviceable and practical C4 text available. Consequently, we will welcome comments, suggestions, and criticisms from faculty, students, and general readers—in short, any feedback that will help improve the text for its next edition. Please address your contributions to:

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Executive Summary

Commentary and readings on command and control have been organized to form a course of ten sessions for military officers. The major topics of the course are:

- The functions of command,
- The process of command and control, and
- The principal features of supporting command, control, communications, and computer systems.

Themes developed by the commentary and readings include the following:

- Appreciation for command and control begins with an understanding of both the responsibilities of command and the nature of warfare.
- There are real and important distinctions between the *process* of command and control and the C^4 *systems* that support it.
- The process of command and control is characterized by the establishment of an organizational structure of decision makers and by a reduction of uncertainty sufficient to permit commanders to make situation assessments and operational decisions.
- The logic of the command and control process is the logic of the military planning process:

  - to decide on a course of action,
  - to develop a plan to execute it,
  - to direct subordinates to execute the plan, and
  - to supervise the execution of the planned action.

- The making of situation assessments (referred to during the course as information decisions) normally requires a flow of information from sensors and reporting commanders through a variety of correlation, filtering,

and analysis processes that convert data into information, and information into operationally useful knowledge.

- Although the reduction of uncertainty is an objective of much of the command and control process, the utility of uncertainty reduction is ultimately limited by the two-sided nature of combat, and the fact that outcomes depend on decisions made by many commanders on *both* sides.
- A commander is clearly an integral part of the command and control process, and should be seen as part of the supporting systems, not separate from them; although there is debate about whether C^4 systems should be designed to adapt to a commander's "style," or whether commanders should have to adapt their command styles to that of the supporting systems.
- The command and control process relies on the shared understanding of separated commanders, an understanding that itself relies on doctrine, teamwork, and previous information exchange.
- Reliance on sophisticated C^3 systems and new technologies (because they offer increased capabilities) may create some new and unprovided for risks and vulnerabilities that need to be recognized and examined.
- As it becomes clearer to commanders on each side that the exercise of command by the opposing commander depends heavily on C^4 systems, such systems will become more attractive as targets for exploitation, manipulation, or destruction.
- Evaluation of a C^4 system may (and probably should) be undertaken in terms of three types of criteria:

  - the performance of its subsystems,
  - its performance as a total system, and
  - its contribution to the success of military operations.

Command and Control

The Literature and Commentaries

Introduction

Purpose and Scope

This course on the command and control of military forces is intended primarily for military officers who have already served in command or who expect to serve in command in the future. The course was originally created in response to a request by the President, National Defense University, who asked that readings on the subject of command and control be identified and arranged in a format useful to faculty who teach the subject at the Senior Service Schools. Its ten sessions review the function of command, the process of command and control, and the principal features of the supporting command, control, communications, and computer systems.

Readings

Bibliography. Most of the readings are drawn from the books listed as "texts" in the bibliography following this preface; the remainder are either selected chapters from the books listed in the "Additional Sources" or are articles drawn from periodicals. The "Required Readings" are listed in the order in which they are recommended to be read, but all bibliographies and lists of supplementary readings are arranged in reverse chronological order of publication, the most recent first. The call numbers that follow entries in the Bibliography are those of the Library of Congress Classification System.

Commentary. The commentary for each session highlights the main themes that will be considered during seminar discussion, and

may also cover supplementary information not included in the required readings.

Required Readings. Following the commentary on the principal topics of each session, there is a summary of each required reading, together with a few questions intended to stimulate seminar discussion or further individual thought. Near the end of each chapter, there is a list of readings and, for some sessions, a case study. The readings, all unclassified, are identified as either required or supplementary, a distinction the instructor may wish to amend. Supplementary readings are listed separately for each major subject of a session, and most of them readings are summarized [in brackets] following their listing.

Sessions

Organization. The course as written consists of ten seminar sessions at which the assigned readings are to be discussed, and at four of which students' papers also are discussed. The course opens with a session on the *functions* of command and the nature of warfare. Part Two of the course examines the command and control *process* over a span of five sessions. The first three sessions of this part are focused on decisions made during the command and control process: decisions about situation assessment, about organizational structure, and about actions to be tasked to subordinates. The final two sessions of this second part are devoted to battles and crises in history in which the success or failure of command and control is thought to have influenced the outcome. Part Three consists of four sessions on the *systems* that support command and control: the first two on C^4 systems for conventional and strategic warfare, the final two on C^4 system architecture and on methods that might be used to evaluate the effectiveness with which C^4 systems support the command and control process.

Sequence. The sequence of sessions was chosen so that several of the principal texts (particularly those by van Creveld, Orr, and Beaumont) could be read straight through over a number of successive sessions. Furthermore, the sessions dealing with the types of decisions made during the command and control process have been scheduled early in the course so that students will have sufficient

time to prepare their papers on historical cases or on C^4 systems, papers that will be discussed during Sessions 5 through 8.

Topics. Topics of the sessions are as follows:

Session 1. Introduction: Command and War

Session 2. Information Decisions/Intelligence

Session 3. Organizational Decisions

Session 4. Operational Decision/Decision Aids

Session 5. Command and Control in Combat/Telecommunications

Session 6. Command and Control during Crises/Computers

Session 7. C^4 Systems for Conventional Force/Interoperability

Session 8. C^4 Systems for Strategic Forces/Survivability

Session 9. C^4 System Architecture

Session 10. Evaluation of C^4 Systems/Conclusion

Participation. Each student is expected to participate actively in the discussions at each seminar session and, in addition, to prepare a ten-page paper, either a case study on how well or how poorly the command and control process functioned during some past battle or crisis (for Session 5 or 6), or a description of some tactical or strategic C^4 system (for Session 7 or 8). A paper on some other command and control topic, including a summary and discussion of the key ideas in one or more of the supplementary readings, might be substituted with the concurrence of the instructor. All papers are to be unclassified. The writer is to distribute copies of the paper to the other students in the seminar and to the instructor on the day prior to the session at which it is to be discussed. The author of a paper will lead its discussion.

PART ONE:

Command and War

SESSION 1
Command and War

The only prize much cared for by the powerful is power. The prize of the general is not a bigger tent, but command.

Oliver Wendell Holmes, Jr.

We have decided to call the entire field of control and communication theory, whether in the machine or in the animal, by the name of Cybernetics, which we form from the Greek for steersman.

Norbert Wiener

Fundamental to understanding C^3I...is to know who you're talking to. If he is a technocrat you can talk to him in terms of a "C^3 system." If, on the other hand, you're talking to a manager...you'd best talk about C^3I, because you're talking about a program—a chunk of the Department of Defense budget. If you're talking to an operator...then you're talking about a process...facilitated by a program. [T]hey [all] have a differing perspective on what it is you're talking about when you say command and control.

Lee Paschall (1980) quoted in
C^3I: Issues of Command and Control

Focus

This session provides an overview of the course and examines the nature of command and the nature of warfare.

Course Overview

The purpose of this course is to enhance the students' understanding of the role of command and control in military operations and war. The intention is not necessarily to prepare officers to take up duties within what might be called the command and control or the C^4 system establishment. The course is primarily for officers who aspire to higher command or who expect to serve as operations or plans officers. The general purpose will be to identify the kinds of problems whose solution may require some understanding of the command and control process and of the general capabilities and limitations of C^4 systems.

The importance of command and control can best be appreciated by considering the penalties for its failure. In a tactical engagement, failure in command and control may result in a tactical defeat, because a commander is unable to bring all available forces into action, to apply them efficiently and effectively, or to prevent them from firing on each other. At the strategic level, failure in command and control may result in the loss of an opportunity either to employ or to disengage military forces, or may cause an unnecessary escalation of hostilities. Tense international situations provide such a small margin for error in the application of force that extraordinary measures are often taken to make sure that command and control does not fail.

The course begins with consideration of the *function* of command and the nature of warfare. The course continues with five sessions on the command and control *process* and concludes with four sessions on C^4 *systems*. The command and control process is examined primarily from the perspective of decision making, where a commander—the decision maker—is distinct both from the people reporting the phenomena on which decisions are based, and from the people who will be tasked to execute the commander's decisions.

Because the term "command and control" is often used interchangeably with the terms "command, control, and communications," "command, control, communications, and

intelligence," or "command, control, communications, and computers," we will begin by defining a few terms for the purpose of this course, but should not expect to find everyone else using the same terms or giving them the same meanings.

The starting point for our definitions is the one given for "command and control" in the Department of Defense (DOD) Dictionary of Military and Associated Terms (Joint Pub 1-02):

> The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures which are employed by a commander in planning, directing, coordinating and controlling forces and operations in the accomplishment of the mission.

Our definition of the *command* function in the definition's first sentence:

> The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission;

our definition of a *command, control, communications, and computer* (C^4) system is based on the middle part of the DOD definition:

> an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander; and

our definition of the *command and control* process is contained in the final words of the DOD definition:

> procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission.

For this course, then, the term "command" will be used to mean the *function* to be performed, the term "C^4" will stand for the supporting *system*, while the term "command and control" will denote the *process* that commanders employ ("in planning, directing,

coordinating, and controlling") as they exercise command authority and direction over assigned forces.

The word "control" when used separately from the word "command" (as in "operational control" or "tactical control") usually means an authority that is less than full command, to be exercised over only some of the activities of a subordinate. For this course, however, the word "control," when used in conjunction with the word "command" to form the term "command and control," is to be understood in its cybernetic sense, and refers to feedback information about friendly units and the current situation that a commander uses to assess the status and progress of own forces and to make necessary adjustments.

The term often used to denote systems—C^3—has over time been expanded to become C^3I or C^4 or C^4I—in order that the contributions of computers and intelligence are made more explicit. Adding letters and exponents makes no real change in the intended meaning. The distinction that is important is not about the term used to denote supporting systems, but about the difference between "system" and "process." During this course, we will use the current joint term—C^4—to refer to the *systems* that support the command and control (C^2) *process*.

The command and control process includes the methods that the commander uses to gather information on which to base decisions, as well as the methods used to insure that decisions are carried out. In establishing a command and control process, a commander at any echelon is likely to have three concerns:

- Whether there are adequate provisions to inform the commander of events that will significantly affect current or impending operations,
- Whether the commander (and staff) will be able to cope with the information received and to transform it into sensible and timely decisions and directives, and
- Whether the directives that implement the commander's decisions will be received, understood, and executed by subordinate commanders in a timely and effective manner.

To accomplish these transitions—from information to directives and from directives to action—commanders make decisions of three

types: operational, organizational, and informational. We customarily think of commanders as focusing primarily on operational decisions about the employment of their forces, but such decisions are made only in light of prior organizational and information decisions. Prior *organizational decisions* have established a chain of command for the execution of operational decisions, as well as establishing a structure for the flow of reports, and for the intermediate processing of information. *Information decisions* are made by commanders to establish what they believe the situation to be, and how that situation relates to the mission they are trying to accomplish. Although information decisions are not always articulated, a commander's *operational decisions* (about what actions subordinate commanders are to take) are always preceded by information decisions about what is actually happening.

There is a tendency to speak of *the* commander, but there are in fact many (interrelated) commanders, and each commander uses a separate command and control process:

- To make information decisions (about the situation),
- To make operational decisions (about actions to be taken), and then
- To cause them to be executed (within a structure established by prior organizational decisions).

In this course, each of these types of decisions will be examined during Sessions 2, 3, and 4. Sessions 5 and 6 will examine historical examples of the command and control process during combat and during crises.

Who *are* the commanders? Which commanders are we talking about? These are important and useful questions, but without answering them completely, we will in this course use the term "commander" to mean officers in command who are at some distance from their subordinate commanders. [In Session 7, there is a related question: who are the *warriors*?] Although there is a unique command and control process for each commander, each C^4 system normally supports the command and control processes of several commanders. During the final four sessions of this course, we will explore C^4 systems: systems for conventional forces, systems for strategic forces, the architectures for such systems, and finally, methods for evaluating them.

Each session of this course is focused on one or two themes, but three subthemes also run through all the sessions. The first of these subthemes is the important role to be played by the *people* in command and control, a role continually being reexamined in light of the improving capabilities of computers and telecommunications systems. A second subtheme is the extent to which the application to C^4 systems of improved *technologies* modifies the command and control process itself. [Should we seize each new technological opportunity or are we held back by the presumption that such improvements may only be marginal or that they create significant new vulnerabilities?] The third is the impact that the underlying organizational *structure* (the balance between centralization and decentralization) has on the effectiveness of command and control, and the ways that the structure affects the roles that machines are made to play and that people choose to play.

This course is unavoidably biased by three assumptions that underlie it. The first of these is that *decision making* rather than information flow is at the heart of the command and control process. The second assumption is that decisions made at the *scene of action* are as important (and may be as difficult) as those made at higher echelons. Unfortunately, commanders who are at the scene of action are less apt to write about their decisions (or write effectively about them) than are commanders or officials at higher echelons. In this course it is postulated that the measure of effectiveness of the command and control process at upper echelons is the effectiveness with which commanders make decisions at the scene of action. The third assumption is that *commanders* indeed make all the key decisions. This historic view is getting more difficult to sustain, as new technologies make possible much increased interchange by both the commanders and their staffs with other decision makers and their staffs, some of whom may be outside the normal command structure.

Command and War

Prior to exploring the command and control process or to examining C^4 systems, we will consider both the nature of command and the nature of warfare. Command is a human activity: the exercise of authority by one person over another. While command may be facilitated (and in some cases may only be possible) by the application of technology, the dominant characteristic of the

command function is its human dimension. Leadership, courage, and human judgment are still decisive, not only in combat itself, but in the selection and preparation of future commanders who will embody purposefulness, creative thinking, and a will to win. This human dimension of command and control is not explored in great depth during this particular course, yet no informed discussion of command and control can proceed without serious consideration of the character and experience of commanders.

Among the foremost considerations that permeate the exercise of command are those of uncertainty and time. One goal of the C^2 process (and a key criterion used during the selection of C^4 systems) is the achievement of a timely reduction of uncertainty, with the objective of facilitating intelligent decision making. As we will see, much of the command and control effort is directed toward the reduction of both uncertainty and time. We will also find that a key characteristic of any military organization is the way that *time* for planning and for the reduction of uncertainty is allocated to the different echelons of command.

Even though the timely reduction of uncertainty is often viewed as the objective of the command and control process, it is important to recognize that the nature of warfare puts some practical limits on our ability to create "ideal" C^4 systems that would eliminate uncertainty entirely. Combat is not a deterministic process. While human decisions may influence combat outcomes, such decisions—some rational, some emotional—are made by the commanders at *several* echelons on *both* sides. Furthermore, under conditions of stress, commanders may not always make their decisions in a reasoned way. While the one-sided aspects of some military operations—movement and support of forces—may be seen as responsive to reasoned decision making, the outcomes of two-sided combat are less so.

Two questions continually present themselves to commanders:

- What is actually happening?
- What (if anything) can I or should I do about it?

The former question requires the commander to make an information decision, the latter, an operational decision. Resolving either question implies some answer to a prior question: What is the mission to be accomplished? Whenever a commander is uncertain

about the mission—what he has been directed or is expected to do—command and control has failed just as surely as if there were no relevant information on the situation or it proved impossible to communicate decisions. While the visible manifestations of the command and control process are the sending and receiving of reports and orders, the process is fundamentally one of decision making about the most effective application of force in the accomplishment of a mission, a process facilitated by the timely reduction of uncertainty.

For this course, the term "operational decision" is not limited strictly to decisions taken at the "operational" level but is used to refer generically to those decisions taken at any level that are intended to result in military action. During combat, most operational decisions to apply force are tactical, made by commanders close (both organizationally and physically) to the scene of action, while operational decisions made at the commencement or termination of hostilities are strategic and made at the highest level. In either case, operational decisions have to be communicated in a way that leaves little uncertainty in the minds of on-scene commanders about what objectives they are to achieve. This communication could take the form of frequent discussions with subordinates as to the general plan and about possible ways an operation might unfold. We will read for Session 5 how Admiral Nelson exemplified a commander who communicated effectively in this way.

Uncertainties in the minds of on-scene commanders tend to be discounted by seniors in the chain of command, who would like to assume that decisions that are perfectly clear in their own minds will surely be fully understood by subordinate commanders. But decisions are not always communicated to subordinates in a timely manner, nor are decisions as communicated always clear to subordinates, nor will the conditions on which the decisions were based continue to prevail. A decision made is not necessarily a decision reliably communicated or clearly understood, unless great effort has been made to create in advance, as did Nelson, the shared understanding that makes communication effective. It is even possible to define command and control as being "whatever it takes" to insure that commanders at the scene of action will take the actions their senior commanders would want them to take under whatever circumstances they confront in a specific situation.

One characteristic of a C^4 system that can be measured is "time," and there is a natural presumption that timeliness has utility. Most uncertainties dealt with in the command and control process can be reduced or even resolved—given enough time. C^4 systems continue to reduce uncertainties about an event as more time elapses, so the product of elapsed time and residual uncertainty remains roughly constant and can be used to characterize the efficiency of a C^4 system: the smaller this product, the better the system. A system that can inform a commander—about the status of own forces, about the location and apparent intentions of an enemy, or about the probable result of alternative courses of action—after only five minutes can be considered a better system than one that requires an hour to produce the same information. It is not very comforting for a commander to be told that the facts and projections needed *now* to decide on effective action might be received eventually. Yet while the quality and timeliness of decisions are generally presumed to be dependent on the accuracy and timeliness of relevant information, such a presumption is of little importance when the information has no bearing on the decision, or changes only slowly.

The time-uncertainty model suggested above is useful as well when considering the command and control process of one's enemy. Because the utility of a C^4 system declines whenever more time is required to resolve specific uncertainties, a commander should try to add to an enemy's uncertainties and to lengthen the time the enemy needs to take to resolve them. Injecting uncertainties to deceive or confuse an enemy's C^4 system, or otherwise to disrupt its functioning, has the effect of increasing the time-uncertainty product of the enemy's system.

There is also in command and control the idea that time is a commodity to be allocated to each echelon for its information processing and planning, and to the executing commander for execution. The total time available for allocation cannot exceed the critical time—the time within which action needs to be taken to be effective. Unless time is apportioned in a way that permits lower echelons to do planning, executing commanders are likely to be short-changed.

While commanders at every echelon understandably view the command and control process as supporting their own decision-making needs, the decision-making needs of commanders in direct control of weapons are the most critical of all. It is therefore important to view the decision making of higher echelons from the

perspective of its impact on the actions of executing commanders. The command and control process at higher levels has not been successful unless the executing commander does the right thing at the right time.

Executing commanders benefit from *organizational* decisions that:

- Create workable command relationships,
- Clearly define the functions to be performed at each echelon,
- Insure an information flow that effectively supports decision making at the scene of action, and
- Insure enough staff and C^4 facilities are available to support operational decision making at the scene of action.

Executing commanders benefit from *operational* decisions by commanders at higher echelons that provide clear operational direction; they could also benefit from *information* decisions, which, if communicated, provide insights to executing commanders about the existing situation itself and about the perceptions on which the operational directives they are executing were based.

Because command ("the exercise of authority") starts at the top, and with modern technology much information is available at the top as well, it is not surprising that great effort has been made to facilitate the command and control process at higher echelons, particularly the processes to be used in crisis situations and nuclear war. It is possible to forget, however, that executing commanders confront decision-making demands that are similar in nature if not in scale, while the uncertainties and urgency they face may be even greater. The quality of decision making at the scene of action should therefore be seen as the true test of the command and control process at higher levels of command.

Commentary on the Readings

In *Command and War*, van Creveld points out that the basic command and control problem is as old as war itself. He uses the term "command systems" to mean the organization, technical means, and procedures used by a commander to exercise command, and he identifies five factors that he feels have caused the great expansion of the command and control problem in recent years:

- The evolving makeup of modern armed forces,
- The rapid development of information technologies,
- The interaction of these two factors so as to modify the nature of command and control,
- The increased vulnerability of C^4 systems, and
- The high cost of C^4 systems.

Has the nature of command and control really changed, as van Creveld asserts? If so, in what way?

In describing the responsibilities of command, van Creveld distinguishes between the function-related problems of internal administration and the output-related problem of accomplishing missions despite the opposition of an enemy. *Is this a useful distinction? If so, which set of problems should we expect command and control to help resolve?*

In outlining the actions required for the exercise of command, van Creveld in effect describes the command and control process: gathering information, estimating the situation, identifying objectives, developing alternative courses of action, deciding on a course of action, transmitting orders understood by recipients, and monitoring execution. You may be struck by the similarity between his command and control process and most descriptions of the military planning process. Van Creveld will later describe this sequence as a process in which information is used to orchestrate men and things toward performing their missions in war, but he then distinguishes this "rational" process from the irrationality inherent in warfare—an enterprise that depends on an appeal to emotional motives. *Would van Creveld agree that the military planning process and his command and control process are really the same?*

Dixon, in an early chapter of his book about ineffective military commanders, describes how commanders failed to take early and effective action during a storm.[1] He explores the role of the commander as an information processor, listing some of the factors

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[1]*Dixon's description of the Great Samoan Hurricane of 1889 is based on Stanley Rogers,* Twelve on the Beaufort Scale. *Melrose, London: 1932, pp. 37-50. For another account see Andrade, Ernest, "The Great Samoan Hurricane of 1889,"* Naval War College Review, *January-February 1981, pp. 73-80.*

that impinge on a commander's ability in wartime to act effectively—like a computer or telephone exchange—and discussing the concepts of information content (entropy) and noise. [We will return to the concept of entropy in Session 5 during consideration of telecommunications.] *Does Dixon's diagram of the processes that a commander follows as he acts as receiver, decision maker, and transmitter of information adequately portray the command and control process?*

In contrast to most discussions about decision making, Orr's book directs our attention to the stochastic nature of combat. His first chapter lays the groundwork for this by outlining some theories about the nature of warfare, particularly those of Sun Tzu, Clausewitz, and Beaufre. He concludes by introducing some of the tenets of maneuver warfare, underlining the contrast between those who see their objective as the physical destruction of the enemy, and those who see it as the confusion and paralysis of the mind of the enemy commander. *How would differences between these objectives affect the command and control process?*

Levis and Athans survey the evolution in thought about command and control that took place during the 1980's. Many of the ideas in this keynote address before a research symposium will be considered during this course, including the distinction between "process" and "system," the role of one's enemy as a factor in system design, and the distinctions between data, information, and knowledge. *Would you agree or disagree with Levis and Athans who conclude that there is as yet no agreed command and control theory, that there might never be one, and yet the search for one will still be worth while?*

Concept, Algorithm, Decision is one of the volumes in the series on Soviet Military Thought, translated under the auspices of the U.S. Air Force. The book—about the theory and methods of decision making—is based on the Marxist doctrinal premise that military activity requires a scientific approach for the solution of both theoretical and practical problems, and that human creative capabilities are expected to increase and expand in the near future as man is liberated from routine functions as a result of the automation of information processing. The authors classify military decisions into three categories:

- Information decisions, about what the truth is;
- Organizational decisions about what the structure will be;

- Operational decisions, about how to act.

The three sessions that follow this one will explore each of these three types of decisions. *Do you find that military decisions can be identified as being either informational, organizational, or operational? Are these distinctions useful? Are there military decisions that do not fall into one of these categories?*

Barnard finds that people he considers to be executives perform the following functions:

- Act as a center of communications (both formal and informal),
- Secure the needed human services, and
- Formulate objectives.

The commanders in a military organization are its executives, and the command and control process is intended to support them as they carry out of their executive functions. *Are the three executive functions outlined by Barnard the same functions that you find military commanders performing?*

Readings

Required Readings

van Creveld. Chapter 1, "Introduction: On Command."

Dixon. "Generalship." Chapter 1, *On the Psychology of Military Incompetence*. London: Jonathan Cape, 1976.

Orr. Chapter 1, "Combat Operations."

Levis, Alexander H. and Athans, Michael. "The Quest for a C^3 Theory: Dreams and Realities," *Proceedings of the 1987 Command and Control Research Symposium*, pp. 7-12, and *Science of Command and Control*, pp. 4-9.

Druzhinin, V.V. and Kontorov, D.S. "Classification of Decisions," Chapter 2, *Concept, Algorithm, Decision: Decision Making and Automation* (USAF translation). Moscow: 1972.

Barnard, Chester I. "The Executive Functions." Chapter XV, *The Functions of the Executive*. Cambridge, MA: Harvard University Press, 1951.

Supplementary Readings on Command

"The Exercise of Command," *Joint Warfare of the US Armed Forces*, Joint Pub 1. Washington, DC: Chairman, Joint Chiefs of Staff, 1991, pp. 35-39. [In a publication that outlines the concepts of joint warfare, this short section on command touches on issues of command structure, on the importance of a "commander's intent," and on qualities of leadership.]

Allard, C. Kenneth. "Paradigms and Perspectives," "The Roots of Service Autonomy," and "Paradigms on Land and Sea," Chapters 1-3, *Command, Control, and the Common Defense*. New Haven, CT: Yale University Press, 1990. [In a book about the tensions between the traditions of Service loyalty and the needs of joint combat, Allard begins by tracing the relatively autonomous developments of the army and the navy up to the end of World War I. He shows how the different combat environments let the Services to differing paradigms for command and control.]

U.S. Marine Corps, "Philosophy of Command," in Chapter 4, *Warfighting* FMFM 1. Washington, DC: Headquarters, U.S. Marine Corps, 1989. pp. 61-65. [This short, useful manual written when General Al M. Gray was commandant, sets out his philosophy of fighting. The excerpt suggested here concentrates on "implicit" communications, the encouragement of initiative in subordinates, and the ability to thrive in the midst of chaos.]

Davis, Ruth M. "Putting C^3I Development in a Strategic and Operational Context." Guest Presentation. *Seminar on Command, Control, Communications, and Intelligence –Spring 1988*, pp.161-174. Cambridge, MA: Program on Information Resources Policy, Harvard University, 1989. [Dr. Davis (who has been involved with command and control during much of its history) traces the evolution of command and control that began in the 1950s. She identifies improvements in "information handling technology" as

being an important driver of that evolution, and with raising the issue of who is the real "on-scene" commander.]

Foster, Gregory D. "Contemporary C^2 Theory and Research: the Failed Quest for a Philosophy of Command." *Defense Analysis*, Vol. 4, No. 3, September 1988, pp. 201-228. [Foster calls his article "a mere prolegomenon to theory," and indeed it is "a formal essay or critical discussion to introduce and interpret an extended work," in this case an issue devoted to the state of command and control theory and research. He feels that a unified theory of command and control can be addressed only after critical scrutiny of the assumptions that underlie four cultures: American national culture, American strategic culture, and general military culture.]

Foster, Gregory D., "The National Defense University's Command and Control Program," in Coakley, pp. 64-67 (to the end of the first full paragraph, "...national security establishment"). (1987) [Feeling that theory is important to command and control because we live in a kind of global battlefield with new tensions between civil and military authorities, and where previous experience may be less relevant than formerly, Foster is looking for a modern theory of command and control to supplant previous theories of leadership, authority, and responsibility.]

Fuller, John Frederick Charles. *Generalship, its Diseases and their Cure: A Study of the Personal Factor in Command.* London: Faber and Faber, 1933. [In this short book, Fuller summarizes his views on the moral, mental, and physical qualities of successful generals during the 19th century and the First World War. He notes that generals are at their zenith at an average age of forty, usually reaching their peak between thirty-five and forty-five.]

Supplementary Readings on War

Herres, Robert T. "Equipment, Personnel and Procedures—Foundations for Future C^3 Architecture," *Principles of Command and Control*, pp. 413-426 (1987). [Outlines the principles of command and control that contribute to "success in battle," emphasizing that command and control is a dynamic

closed-loop process that takes place at each level of command, and concludes that the total command and control process should therefore be seen as a multitiered series of related closed-loop (but interdependent) processes.]

Clausewitz, Carl von. "On Military Genius." Book One, Chapter Three, *On War*. (1832) Princeton, NJ: Princeton University Press, 1976. [Clausewitz describes "military genius" and elaborates on those aspects of intellect and strength of character that he feels distinguish the superior commander: courage, determination, presence of mind, a sense of unity, and a power of judgment. We may wonder whether these qualities are enhanced, or perhaps diminished, by supporting C^4 systems.]

PART TWO:

The Command and Control Process

SESSION 2

Information Decisions / Intelligence

Many intelligence reports in war are contradictory; even more are false, and most are uncertain.

Clausewitz, On War

I can speak from first-hand experience. We were engaged in low-level attack. We were right down on the targets, bombing and strafing them at treetop level. There were certain things we saw and reported, and yet it turned out, when we got the photographs back, that we were wrong. And if you think that's changed today, you're wrong, because it hasn't. What is reported about the battlefield or the airspace, and the actual fact of the case, may be two entirely different things. And that's why this is an iffy business.

Richard H. Ellis (1982), quoted in
C^3I: Issues of Command and Control

A cardinal rule in an establishment as large as the Department of Defense is to assume that first reports are always wrong, no matter what their security classification, no matter to whom they are addressed.

Phil G. Goulding, *Confirm or Deny*

There was a time when you had to fit all that you needed to say on the entire world every 24 hours into four pages. It didn't matter if it was the holocaust in Cambodia or a Soviet missile test. You had to fit everything

in four pages....Don't confuse the ability to prepare intelligence in an efficient way with getting through to the person you're trying to reach.

Lionel Olmer, Esq. (1986), quoted in
C^3I: Issues of Command and Control

Focus

This is the first of three sessions about the decisions that dominate the command and control process; we will here examine the information decisions that commanders make as they assesses the situation.

Information Decisions

Decisions about action must be preceded by decisions about the situation. Prior to making decisions about what action to take, commanders make decisions (whether they articulate them or not) about what is actually happening: about which course events are taking. Despite all the messages, briefings, and intelligence that a commander receives, it is the commander's information decision about the "state of nature" that becomes the basis for further (operational) decisions. Commanders make decisions on the basis of what they *believe* is happening. This raises some fundamental issues: *how* do commanders come to know what they think they know? what *confidence* should they have in what they think they know? and despite what they know about recent events, what is happening *now?*

C^4 systems are in great part devoted to providing commanders the information they need to assess a situation. But the uncertainties that surround such information are many: the information available is usually incomplete, conflicting, or ambiguous; it often arrives late, after having been transmitted imperfectly or received with error; and it may be misunderstood or misinterpreted. Even though a commander's uncertainties about an event are usually reduced over time following the event—as amplifying and clarifying reports are received and understood—commanders usually have to make up their minds about what action needs to be taken long before the situational uncertainties can be resolved completely.

Commanders are continually making information decisions that define the current situation as they see it. Yet in many military

situations, both in combat and during crises, the critical judgement may be whether the situation has *changed* sufficiently to justify drawing conclusions that enemy strengths, enemy objectives, or enemy rules of engagement have now altered. Thus the evaluation of new information in the context of the patterns of the past needs to be accompanied by a willingness to recognize that those patterns may now have changed. The making of such evaluations benefits from close and frank cooperation between the operations and intelligence portions of a commander's staff and may reveal the need to employ additional sources to support the commander's ability to make reasonable information decisions.

Although the command and control process may seem similar at all levels, it has a different focus at each echelon. At higher levels, policy consequences guide decision making; at lower levels, survival and mission accomplishment dominate. Information is needed both for planning and for execution. At all levels, prudent commanders try to anticipate likely situations, think them through, and create plans to deal with them; problems that have not been thought through in advance are less likely to be solved effectively under the pressure of a rapidly evolving situation.

If the several levels in the chain of command are provided with essentially identical portrayals of actions by both enemy and friendly forces, their ability to discuss with one another their assessments of evolving situations will have been greatly facilitated and the likelihood of mind-to-mind communications between them will have been enhanced. If they already share a common appreciation for the significance of unfolding events, they are more likely to achieve a common understanding of what is actually happening.

The degree to which fresh reports are fully understood depends to some extent on the amount of *previous* information exchange. While we customarily visualize a report as transporting the information contained within it, we should really think of a report as announcing to its receiver which one of the possible situations already visualized by both sender and receiver is now actually occurring. Thus, when a truly unexpected situation arises, we should not be surprised to find that a reporting system has to work much harder if it is to convey effectively information that is indeed unanticipated.

Two recent technological developments have significantly affected the tempo of the command and control process. The first is that modern forces, employing stealth and high speeds, can be generated and applied over great distances in a matter of hours or even minutes, with strategic consequences. The second development is that a superpower now has, literally, worldwide surveillance coverage of potentially hostile forces and activities. Taken together, these developments have vastly enlarged the amounts of information that can be brought to bear on a problem and have greatly accelerated the speed with which intelligence is needed or expected by commanders.

Much surveillance data is converted into comprehensible forms and fused with other data and then distributed to interested commanders in the field. This system is maturing and changing: new technologies now facilitate greater tailoring of information for field commanders; the same raw data is increasingly used to develop "strategic," "theater," and "tactical" intelligence. Several risks remain: that analysts at one level will not always recognize which data has tactical significance for commanders at other levels, and that analysts at all levels will focus so narrowly on current intelligence that they will be blind to indicators that should provide them long-term strategic warning.

People closer to the scene of action are assumed to be somehow better informed about what is happening there. Commanders whose forces are in contact with those of an enemy should indeed be receiving information about the enemy from those forces. Commanders at the scene of action are directly aware of local environmental conditions and how such conditions can permit or inhibit actions on each side. During combat, local commanders are also aware of the specific types of weapons being used, a factor to be considered during battle damage assessments.

Those at the seat of government assume that a theater commander is knowledgeable about local environments and about the kinds of information needed by the forces. From the perspective of those at the seat of government, a theater commander takes on the appearance of an "on-scene" commander and is presumed to be engaging in a detailed management of the application of force. To satisfy these expectations—which may or may not be justified—theater commanders can be expected to become more vigorous in seeking information from on-scene commanders.

Intelligence

Much (but by no means all) of the information on which a commander relies to make decisions is provided by intelligence officers and derived from the intelligence process. In that process, information rarely moves in its raw state directly from sensor to decision maker; it passes not only through the "links" in a reporting system but is processed at system "nodes," where it is filtered, correlated, and analyzed: three functions that may be performed at one point or at several. The observations gathered by sensors are likely to be numerous, so *filtering* is used to suppress reports that are redundant or that fall outside some reporting threshold. Establishing thresholds to limit the frequency of reports or to specify the range of acceptable values may be important as control mechanisms, but such thresholds need to be reevaluated as the situation changes so that necessary but unexpected information will not be filtered out.

Correlation is the process of establishing whether the same object is the subject of different reports: reports by different sensors at the same time, by the same sensors at different times, or by different sensors at different times. Whether or not two reports refer to the same object is not always obvious, and much of the correlation effort has therefore to be directed toward making such determinations. Because reporting delays may vary, observations made at the same time may reach users at different times, so the correlation process needs to account for this lack of synchronicity. The identification and removal of "ghosts," non-existent targets, as well as false targets introduced by enemy deception, are sometimes attempted during the correlation process. Correlation may also try to establish positions, movement, identities, and perhaps the state of readiness. Uncertainties exist here, too, and some correlations may be tentative or made with less than full confidence. When commanders urgently need to decide what is happening, they may discount or completely disregard such uncertainties. One of the tough challenges of C^4 system design continues to be the creation of graphic displays that portray the degree of uncertainty that remains after the correlation process.

A third process, which takes place at the commander's headquarters as well as at nodes somewhere between the sensors and the commander, is *analysis*, the drawing of inferences from correlated data. Such inferences might concern an enemy's intentions, tactics, or rules of engagement. Uncertainties exist here as well, because

important information may still be outside the system, or because the C^4 system itself may not be transmitting or presenting the available information with sufficient fidelity.

And if the unresolved uncertainties were not enough, the commander needs to recognize that the processes of filtering, correlation, and analysis are themselves imperfect, that an active enemy may be engaging in deception, and that commanders' decisions will be made on the basis of information *as perceived* through whatever biases shape their thinking. Because of historic failures by governments and commanders to recognize indications of warning, having been "blinded" by current (or even past) intelligence, some people have postulated that the failure of warning is inevitable. *If the failure of warning is not inevitable, what might be done to reduce the likelihood of such failures?*

"Fusion" is the process of integrating information from one two or more sources. "Fusion centers" filter, correlate, and analyze information from a variety of sources, and act now as nodes in the network of information flow to a number of commanders. Fusion centers have been used to facilitate wider distribution of information derived from sensor systems with severe security constraints. The fusion process makes possible the introduction of such information whenever sources with lower security levels could have been the source.

Fusion centers, however, usually do not carry out operational tasks, and although they provide filtered, correlated, and analyzed information to a number of commanders, they are necessarily under the command of only one of them (or sometimes none of them). To this extent, an important part of the C^4 system that supports some commanders may be beyond their direct or even indirect control. Nevertheless, any commander served by a fusion center should attempt to influence that center to make its intermediate information decisions in a way that conforms to the commander's sense of priorities. Just because the same raw data may yield information useful to several echelons of command, it cannot be assumed that all analysts will be able to recognize its significance for each commander served.

As information flows from sensor to commander, there is a sense of progress from data to information to knowledge. In a related but different sense, information that flows from the bottom of an organization to the top usually (but not always) becomes more ag-

gregated. But all information is not equally understood, useful, or valuable. To be understood, it needs to be displayed in terms that match the commander's logic; to be useful, it needs to be aggregated at the level appropriate to the types of decisions being made; and to have value, it needs to be reliable, timely, and relevant to some *decision* that the commander will make. Ever where fusion centers exist, there are always *two* fusion problems: the fusion of all-source information, which takes place at the fusion center itself, and each commander's merger of *that* information with the information received directly from sources under their control.

In a hierarchical organization, authority is delegated to subordinate commanders to take action within some area of discretion. Such a delegation of authority to take action has also been interpreted to imply that subordinate commanders have similar discretion to screen out information. Yet senior commanders, looking to their own decision-making needs expect subordinate commanders to furnish them full information. On the assumption that the amount of real control by each echelon is somehow related to the amount of information there, some subordinate commanders avoid sending up unevaluated information and send only what they believe their seniors want to hear. They are concerned that as more information goes up, less authority will be delegated downward.

To counter this tendency, some senior commanders have sought out information by separate means in order to view it from their higher perspective. They do so because they are also alert to the possibility that subordinate commanders, operating with a different perspective, might overlook or misinterpret the significance of some of the information at their disposal. A senior commander might employ what van Creveld (on p. 75) calls:

> a directed telescope which he can direct, at will, at any part of the enemy's forces, the terrain, or his own army in order to bring in information that is not only less structured than that passed on by the normal channels but also tailored to meet his momentary (and specific) needs.

The conventional view of command and control is that it is "information-intensive," driven by increasing amounts of *information* "pushed" through C^4 systems by sensors and by reporting commanders. This flood of information, carefully reviewed and

analyzed, is assumed to form the basis for action. The alternative view is that command and control is really "information-decision intensive," and that *decision making*, not information, is the key to command and control. In this view, information ought to be seen as having been "pulled" out of the system by commanders who have requested it. Such commanders have first identified the decisions they can expect to make, then determined what information might reasonably be expected to contribute to the quality of those decisions, and finally actively sought out such information, either by using their own resources to obtain it or by requesting from higher operational commanders whatever essential elements of information (EEIs) were unobtainable by their own resources.

The seeking of information includes not only requesting it from fusion centers and senior commanders, but allocating some portion of one's force for employment primarily in collecting and reporting information to support one's own decision making needs. In either case, it becomes necessary to suppress whatever information is irrelevant so that reporting and analysis systems (as well as commanders and their staffs) can concentrate primarily on information essential for decisions. Both the "information intensive" and the information-decision intensive" schools of thought are active.

Among the new factors that commanders may have to take into account is the so-called "CNN effect," the possibility that widely available open-source information might influence the commander's decision making. As a result of swift dissemination of open-source information about contemporary events (and even about reactions to those events by foreign governments and by senior officials in our own government), commanders may now have more insight about events described in classified intelligence reports and in classified tasking directives. Yet there is a risk that the continuous "open-line" nature of such real-time reporting may encourage commanders to defer making their information decisions because of the expectation that some clarifying report may shortly arrive.

Commentary on the Readings

Van Creveld characterizes the period prior to 1800 as the "Stone Age of Command." As the enduring parameter that governs strategy, he identifies information about one's own forces, about the enemy's forces, and about the environment. He emphasizes that the rate of

change of information varies, and that *timeliness* of intelligence depends both on the speed with which information can travel and on the rate of change of the information itself. The factors that affect the rate of change—mobility, speed of decision making—and the factors that determine the rate at which information can travel are different, but both need to be kept in mind. He notes the kind of tradeoffs that have always existed between speed of transmission and reliability (or capacity).

As he will throughout his book, van Creveld reminds us that there are always two problems for the commander—how to fight the enemy and how to exist in the field—and he considers the latter problem to be the greater. He concludes that staffs were originally intended to relieve commanders of the administrative detail of the day-to-day running of armies. As for fighting an enemy, van Creveld believes that because of the primitive nature of communications, commanders have historically tried to position themselves on the battlefield where they could exercise control over the forces at the place that was expected to become the decisive point. He concludes that the Romans developed the most successful solution to battlefield command problems by:

- Relying on standardized formations,
- Establishing proper organization at the lowest level,
- Employing a fixed repertoire of tactical movements, and
- Diffusing authority in order to reduce the need for detailed control.

Would you expect to find such a command "style" to be equally effective today?

The assigned chapter in *Concept* discusses information sources, information channels, and the logic by which information decisions are made. The authors characterize information sources by their range, completeness, accuracy, and reliability. Information channels are subject to both technical distortion and semantic distortion. The chapter then outlines in some detail three different logical methods that commanders might use to arrive at an information decision:

- Correlation (comparison): assessing the probability of the truth of *reports* by comparing them to *a priori* thresholds based on experience;
- Filtration: formulating possible *decisions* beforehand, identifying their characteristics, and deriving weighted parameters against which reports are compared;
- Situation (pattern) recognition: forecasting *outcomes* based on past experience in analogous circumstances.

The authors illustrate these three methods of decision making by showing how they were used by characters in an American novel. *How does the method that a commander uses to arrive at information decisions make a difference in the design of C^4 systems that support him?*

In his second chapter, Orr attempts to build a model of combat operations. He applies various theories of warfare—as well as the observation-orientation-decision-action model of John Boyd and the thermodynamic model of J. Lawson—to postulate what Orr calls the "combat operations process model," portrayed in his figure 4. He then identifies two subsidiary models—a "power distribution model" (really a model of combat, to be fully described by Orr in his next chapter) and a "military problem-solving process model" (in effect, a decision-making model). He then describes various theories of information processing and decision making. *Do you find his "combat operations process model" useful? Which of the methods of decision making that he describes most resembles the way you find decisions actually being made?*

Faurer describes and discusses the functioning of the National Security Agency, and how signals intelligence supports the military commander. He discusses the role of fusion centers, how automation has accelerated their development, and how centralization-decentralization issues arise. *Do you agree with his conclusion that intermediate fusion centers are preferable to direct delivery to tactical commanders? What are the counter arguments in favor of direct delivery?*

Inman reviews the intelligence community's evolution during the 1950s, 1960s, and 1970s. He highlights the several balances that need to be struck between:

- Collection and analysis.

- Manual and machine-assisted operations, and
- Protection of sources and wider availability of intelligence products.

He refers to the huge volumes of data generated during a crisis which can be dumped on commanders and their intelligence staffs, and hints that while "fast and accurate" intelligence is desired, what is needed is the skill to recognize quickly what is relevant and what is not. *Is this consistent with your own experience?*

Readings

Required Readings

van Creveld. Chapter 2, "The Stone Age of Command."

Druzhinin, V.V. and Kontorov, D.S. "Information Decisions," Chapter 3, *Concept, Algorithm, Decision: Decision Making and Automation* (USAF translation). Moscow: 1972.

Orr. Chapter II, "C^3I and the Combat Operations Process."

Faurer, Lincoln. "The Role of Intelligence within C^3I," in Coakley, pp. 323-334.

Inman, B.R., "Issues in Intelligence," in Coakley pp. 309-314.

Supplementary Readings on Information Decisions

Woodcock, E.R. "Indications and Warning as an Input to the C^3 Process," from *Proceedings of the 1987 Command and Control Research Symposium*, pp. 83-92, and *Science of Command and Control*, pp. 22-47. [An attempt to close the gap between the command and control of forces, and the indications and warning activities that convert sensor-derived data into alerts. Woodcock suggest that catastrophe theory—which deals with systems in which minute changes result in sharp discontinuities—may provide insights into the environment of modern combat.]

Waltz, Edward L. and Buede, Dennis M. "Data Fusion and Decision Support for Command and Control," *Principles of Command and Control*, pp. 213-236 (1986). [Distinguishes the data fusion function that assists commanders performing situation assessment (equivalent to our "information decisions") from the decision support function that assists commanders doing alternative analysis (equivalent to our "operational decisions"), and applies Wohl's stimulus-hypothesis-option-response (SHOR) paradigm, which emphasizes this distinction. They identify typical parameters for three different tactical situations—naval, air, and ground—and describe the use of data fusion and decision support in each.]

Jervis, Robert. *Perception and Misperception in International Politics*. Princeton, NJ: Princeton University Press, 1976. [Describes the decision-making process at the policy-making level, and emphasizes the importance of understanding how alternative actions might be perceived by others.]

Barnard, Chester I. "The Theory of Opportunism," Chapter XIV, *The Functions of the Executive*. Cambridge, MA: Harvard University Press, 1951. [Describes the analysis that precedes decision making as the process of "finding what conditions are significant to the attainment of the desired purpose." Barnard describes that process as a search for the "strategic factors," whose control will establish the set of conditions that accomplish the purpose of the organization.]

Tolstoy, Leo. *War and Peace*. (The Battle of Borodino: Part (or Book) X, Chapters XXIV to XXXIX, and Part (or Book) XI, Chapters I and II.) [Conveys a sense of the uncertainties surrounding combat operations, in this case, at Borodino. The novelist describes the arrival of reports that advised Napoleon and Kutuzov of the changing situation, as well as of the frequent and urgent requests they received for reinforcements.]

Supplementary Readings on Intelligence

Rechtin, Eberhardt. "Command and Control in the Years 2000+," *Principles of Command and Control*, pp. 464-470 (1987).

[Rechtin describes the increasing use of wide area surveillance systems and predicts that the widening of combat horizons will shrink the autonomy of commanders at the scene, suggesting that some other organizational changes are likely to result as well. He further speculates that to avoid the effects of an opponent's wide area surveillance, the collocation of operational commanders with large headquarters staffs will be unwise, and that future command configurations may come to resemble those of guerrilla commanders, in recognition of the fact that the increasing availability of wide area surveillance has an importance for command and control far beyond that of providing additional information.]

Layton, Edwin T. *"And I Was There": Pearl Harbor and Midway—Breaking the Secrets.* New York: William Morrow, 1985. D767.92.L39 1985. [A first-person account of the role of radio intelligence prior to the Japanese attack on Pearl Harbor and throughout the war in the Pacific, by the intelligence officer on the staff of the Commander-in-Chief, U.S. Pacific Fleet.]

Daniel, Donald C. and Herbig, Katherine L., eds. *Strategic Military Deception.* New York: Pergamon Press, 1982. [A collection of articles that examine the role of deception in warfare.]

Wohlstetter, Roberta. *Pearl Harbor: Warning and Decision.* Palo Alto, CA: Stanford University Press, 1962. [Details the warnings of the Pearl Harbor attack available at the time to U.S. decision makers, who were nevertheless surprised in the midst of warning signals. The book is based on congressional hearings, official histories, and the personal memoirs. It vividly outlines the difficulty in recognizing, selecting, and correctly interpreting relevant information in the presence of noise. The author recommends that we accept the existence of uncertainty and learn to live with it. A more recent book, *Pearl Harbor: Final Judgement* by Henry C. Clausen (appointed by the Secretary of the War to investigate) and Bruce Lee, New York: Crown, 1992 (D767.92.C58 1992), focuses on the failures of individuals, on the shortcomings of faulty procedures, on the lack of genuine sharing of information between the Services, and on the

difficulties caused by the special handling imposed on the distribution of information.]

Clausewitz, Carl von. "Intelligence in War," Book One, Chapter Six, *On War*. (1832) Princeton, NJ: Princeton University Press, 1976. [Taking a skeptical view of intelligence, Clausewitz discusses some of the factors that tend to reduce the quality of intelligence reports and to minimize their usefulness when received. He suggests that because people tend to believe bad news more readily than good news, they should err on the side of hope rather than of fear.]

SESSION 3
Organizational Decisions

Command and control involves a good many things that you don't normally think about: an organization for decision-making; a structure that you hold inviolate for the transmission of instructions downward—although you can skip echelons on the way up for information purposes; and people who understand the mission, who are drilled in the doctrine and the procedures that constitute teamwork.

Richard G. Stilwell (1985), quoted in
C³I: Issues of Command and Control

What makes an organization work? It is the men who compose it! The first thing you have to work out is whether or not the people at the top are not only going to be a fine, interlocking mechanism themselves but whether their example is going to go on down through the whole organization, to make for you a successful fighting team.

Dwight D. Eisenhower (1950),
Address to the National War College

Don't partition [systems] by slicing through regions where high rates of information exchange are required.

Eberhardt Rechtin in *System Architecting*

Focus

In this session we examine the organizational options available to a joint commander for the organization of forces, and we discuss the implications that a commander's organizational structure has for command and control.

Organizational Decisions

Organizational decisions establish a chain of command—the line of authority for getting a job done—as well as a chain of responsibility for success or failure. But beyond that, organizational decisions create a command and control structure and specify the roles that each commander is expected to fulfill in the command and control process by establishing "who decides what." Finally, organizational decisions establish the web of functions and relationships that C^4 systems are expected to support. It may be said that "every organizational decision is also a C^4 system decision."

Organizational decisions create a structure that establishes not only how operational decisions get executed but also where commanders get their information and on whom they rely for advice. An organizational structure should identify for commanders the organizations that are supposed to provide them inputs of information as well as the organization to whom they will send their decisions and reports. Thus, organizational decisions usually create a structure that:

- Reflects the lines of authority and responsibility,
- Establishes the flow of information, and
- Identifies which commanders are empowered to make which decision.

Whether made by the commander or by some superior, *organizational* decisions:

- Support the making of *information* decisions by identifying which organizations may be tasked to obtain

information, and by structuring the flow of information and advice to the commander,

- Support the making of *operational* decisions by structuring the flow of advice to the commander about the utilization of forces, and
- Facilitate the execution of *operational* decisions by establishing a chain of command.

On the information (input) side of their decision making, commanders want to tap whatever sources can provide the information needed to support sound decision making while avoiding, if possible, being at the mercy of a single source for any particular kind of information. For the purpose of obtaining information from sources *outside* a commander's own control, the operational chain of command upward also defines the chain for validating and prioritizing intelligence requirements; when a commander's operational chain of command is changed, so is the path for requesting intelligence support. A commander sends essential elements of information (EEIs) up the chain using formats developed by the intelligence community. Because the validation process is intended to reflect the *operational* judgement at each level in the command chain, commanders may find it necessary to persuade higher echelons of the importance of their operations. With respect to advice about operational decisions, a commander might want to rely on a mix of advice from sources both internal (the commander's staff) and external (other commanders, particularly subordinate and component commanders).

On the execution (output) side, the objective of organizational decisions usually is to achieve "unity of effort" in the execution of decision. Whether a commander believes that unity of effort can best be (or can only be) achieved by unity of command is reflected in organizational decisions. Another objective may be to balance forces and tasks to obtain "an equal strain on all parts," or so that relative strengths of forces reflect relative priorities of tasks. An often overlooked implication of hierarchial organizations is that they specify the immediate subordinate commanders to whom orders will be directed. Even though the decisions of commanders at every echelon may be intended to affect operations at the scene of action,

their orders are normally directed for action to commanders only at the next lower echelon.

The making of organizational decisions requires resolution of the following issues:

- Whether the command is to be organized on an area or functional basis; whether subunits will be clustered by skills or by tasks;
- Whether the organization will be narrow or broad, that is, whether commanders will exercise command over a few immediate subordinates or many; and
- Whether authority will be centralized or decentralized.

Several options are available for organizing a military force. In general a command may be divided and subdivided by one or more of the following methods:

- By area (that is, by grouping together all forces within a geographic area from whatever Service or Nation or for whatever purpose).
- By Service or Nation (that is, by grouping in each subdivision all forces from only one Service or Nation).
- By medium (that is, by grouping together all ground forces, air forces, and seaborne forces from whatever nation or service), or
- By task (that is, by grouping together all forces directly involved in accomplishing the same task from whatever service or nation.)

Some organizational structures (such as the Unified Command Plan) reflect a mix of the above options. One of the organizational dilemmas is that while organizing by function (or skill) promotes *efficiency*, organizing by task tends to promote *effectiveness*. Under what circumstances or in what types of conflict would you expect each method to be superior to the others?

Every organizational decision is, in effect, a command and control decision. An organizational decision establishes command and reporting relationships that shape the C^4 system and commit C^4 resources. Such a decision requires subordinate commanders and their

staffs to communicate, to perform the situation assessments that lead to information decisions, and to make the necessary operational decisions. The requirement to communicate creates the need not only for the physical links but also for staffs that share vocabularies and doctrine, and are able and willing to be effective communicators in the larger sense. Commanders about to make organizational decisions therefore need to take into account the capabilities of individual subordinate (and other) commanders, of their staffs, and of their C^4 facilities to perform whatever tasks are implied by the candidate organizational structures.

Organizational decisions about U.S. military forces include the following five types of decisions:

- Decisions (at the national level) about the establishment and responsibilities of the unified and specified combatant commands;
- Decisions (by the Services) about the organization within Service tactical formations (e.g., Army divisions, Navy battle forces, Air Force tactical fighter wings, Marine air/ground task forces);
- Decisions (by the combatant commanders) about the command structure (usually a joint task force commander) that connects them with their subordinate (Service) tactical commanders;
- Decisions (by the Services) that affect the ability of Service tactical formations to coordinate and interoperate with those of other Services; and
- Decisions (by joint task force commanders and other on-scene commanders) about the relationships between tactical formations and the organizations that provide their intelligence, logistics, and telecommunications support.

Decisions about the establishment of combatant commands are promulgated in the presidentially approved Unified Command Plan. Decisions about the organization of Service tactical commands are normally made in accordance with Service doctrine. Decisions about the command relations between combatant commanders and the tactical commanders are made by the combatant commanders, who in accordance with *Unified Action Armed Forces* (Joint Pub 0-2) have

several options, including the establishment of joint task forces. [A force is termed "joint" when forces from two or more military departments participate, and "combined" when forces of two or more nations participate.]

The level of interoperability that can be achieved between tactical formations is determined in the first instance by the decisions made by the Services as they equip and train units, then by the combatant commanders as they organize and exercise joint forces, and, finally, by the executing joint commander. [The implications of such decisions will be considered in more detail as part of Session 7,"C^4 Systems for Conventional Forces: Interoperability."] Decisions about the relationships between tactical formations and organizations that support them are normally made by some common superior.

At what level in the chain of command does the organizational structure change from being joint to being a Service organization? It is clear that at the top, the military effort will be unified, but at the bottom, forces expect to fight as part of some (however small) Service unit. The history of the Unified Command Plan since World War II has been the story of moving that transition point ever lower. At one time the transition from "joint" to "service" occurred at the Joint Chiefs of Staff (JCS), when the Service Chiefs acted as Executive Agents for the JCS. Later it became clear that the transition from "joint" to "service" was to take place between unified commanders and their Service component commanders. Now that the use of joint task forces has become more prevalent, it might be assumed that the transition is to occur between the commander of the joint task force and immediate subordinate (Service) component commanders. Yet commanders of joint task forces may (and, arguably, should) choose to organize their forces on a "task" basis in order best to get the job done, despite the difficult interoperability problems that can arise when there has been no prior planning or exercises.

Whenever task-oriented organizations are needed on a more or less permanent basis, as they are now for anti-drug operations, standing joint task forces are likely to be formed. For situations that can reasonably be anticipated, plans are likely to call for the creation of joint task forces when needed. But for the truly unexpected crises, the formation of joint task force is like to fully stress the command and control structure. Joint commanders, their staffs, and their forces need time to prepare for a joint operation, yet a crisis usually has to

be dealt with so quickly that adequate preparation time is not available. Nevertheless, the use of joint task forces at the scene of action is likely to increase, raising some interesting questions about command and control: *Who should be chosen to act as joint task force commanders? Where should their staffs come from? What command facilities should they use for the exercise of joint command? Are existing Service facilities adequate?*

On the basis of experience in recent years, it seems clear that for major crises that require significant forces, Joint Task Force commanders will be selected from Numbered Fleet Commanders, Army Corps Commanders, Numbered Air Force Commanders, and Marine Expeditionary Force Commanders. *While they perform the duties of joint task force commander, should they continue to act in the Service capacity, or should they turn their Service job over to a deputy? Should the staffs of these commanders be joint all the time, or is it sufficient to augment them only when needed? Should afloat flagships and other mobile headquarters be considered for use by Joint Task Force Commanders, regardless of Service? On what basis will it be possible for joint task force commanders to estimate the level of interoperability that will exist among their joint forces?*

The trend toward increasing use of joint organizations is not the only reason for commanders to realign their organizational structures. Historically, the introduction of major new technologies has been followed by the development of a new organizational structure to optimize its exploitation. The introduction of radar and guided missiles are examples of developments that created the opportunity for new and different organizations. The important consideration for this discussion is that the creation of any "new" organizational structure requires a corresponding realignment of C^4 systems to support it.

In summary, organizational decisions represent important structural choices made by commanders at every level, choices that exert a major influence on the process of command and control and on the structure of C^4 systems that will support that process. Whenever organizational options are being considered, whether or not an estimate of the situation is being developed, the appropriate staff action would be to prepare a Command and Control Estimate (formerly the Communications Estimate) in order to inform the commander of the relative feasibility with which C^4 systems can

support each alternative under consideration. Finally, we should not forget that commanders at all levels tend to be oriented downwards, greatly concerned with the performance of processes and systems of subordinate commanders, while remaining relatively indifferent (or even hostile) to the performance of systems of higher commanders.

The foregoing discussion of organizational decisions has emphasized *structural* aspects that specify the relationships between commanders and establish the lines along which orders and reports may be expected to flow. But structure alone is insufficient to fully describe actual command and control relationships. It is necessary to understand as well what *authority* has been delegated to each commander. Even though much of the authority of commanders is established by regulation or by custom, some authority may be withheld at will by senior commanders, including the National Command Authorities. The authority delegated to combat units to use force may be carefully crafted for each situation. In practice organizational decisions that delegate or withhold authority may be in the form of rules of engagement, which have therefore become a key element of command and control as it exists in the real world.

Commentary on the Readings

Van Creveld describes the command and staff organization used by Napoleon. There are two themes in his description: the first is the balance to be maintained between detailed direction by a centralized authority on the one hand, and the use of initiative and discretion by subordinate commanders on the other; the second theme is the need to exploit the opportunities provided by new technologies while at the same time recognizing—and if possible transcending—the limitations such technologies impose.

Napoleon would solve the centralization/decentralization dilemma by:

- Organizing self-contained mission-oriented units,
- Instituting a system of standardized reports and orders,
- Establishing a headquarters staff to deal with reports and orders, and
- Instituting a "directed-telescope" system of adjutant generals to provide alternative sources of information.

This directed-telescope idea will be revisited by van Creveld in subsequent chapters as he describes how later commanders sought to obtain information to support their own decision making, not wanting it filtered by subordinate commanders or in some cases even by their own staffs.

A key organizational decision for any commander is how to divide the force. Napoleon's solution was to organize his army into corps, each sufficiently large so that it could not be overwhelmed in the time required for another corps to come to its rescue. Van Creveld's detailed description of Napoleon's command and control process in action at Jena illustrates the tendency for commanders to intervene operationally in a detailed way at the place where they are physically located. (Jena is also a fine example of the nature of warfare: Napoleon learns that he just won a great battle that he had not even known was taking place.) *Do Napoleon's solutions to both the centralization/decentralization dilemma and to the question about the size of subordinate units still make sense today?*

Admiral Metcalf was the joint task force commander of Operation Urgent Fury in 1983. His description of the problems he faced at Grenada and of how he resolved them spans both information and operational issues as well as organizational ones, but is included here with readings about organization decisions because it provides a revealing insight into the importance he placed on his personal relationships with the commanders at both higher and lower echelons in the chain of command.[1] Metcalf concludes that command and control should be kept simple, that face-to-face contact is important, and that therefore a joint task force commander should be on the scene. In order to be at the scene, he shifted from his regular flagship

[1]*Metcalf's remarks were delivered at a conference that was exploring decision making under conditions of ambiguity. The "garbage can" model of decision making referred to in the text postulates that decisions made in large organizations relate more to the interests and available energy of the decisions makers than to the importance or urgency of apparent problems or to the availability of acceptable solutions.*

USS *Mount Whitney* in Norfolk to the smaller USS *Guam*, which he shared with his amphibious task force commander.[2]

As you read his description, consider the command and control implications of three of the key organizational decisions that he made:

- To establish his command post in USS *Guam*.
- To conduct two separate ground operations (one north, one south) with the commander of each reporting to him.
- To retain the existing command relationships to the Marine company that was recommitted to the ground operation in the south, and to avoid potential problems of mutual interference by changing the boundary lines.

Admiral Ernest J. King, USN, when he was Commander in Chief, U.S. Atlantic Fleet in the year just prior to the U.S. entry into World War II, wrote two letters that contain his efforts to articulate a command philosophy intended to encourage the initiative of subordinates. (The fact that it required two letters to make his point precisely should warn us that communicating one's command philosophy is not easy.) *Would you have adopted a similar philosophy of command under similar circumstances? Could such a command philosophy realistically be pursued today?*

In his third chapter, Orr describes in some detail his "power distribution model" of combat. He argues that command of combat operations is vastly different from command of other military activities because combat outcomes tend to be more stochastic and less controllable than the results of other activities. He analyzes four types of systems along a deterministic/stochastic dimension. He points out that while a commander's decisions may *influence the probabilities* of combat outcomes, they do not *determine* combat outcomes, and that useful predictions of such outcomes are therefore difficult to make. He concludes that what a commander really does is to manage the sources of potential power (which Orr calls the power distribution) as a way of influencing combat results in the

[2]*For another view of the organizational and personal relationships during Operation Urgent Fury, see the memoirs of Metcalf's deputy, Norman Schwarzkopf, in pages 244-258 of* H. Norman Schwarzkopf *(New York: Bantam Books, 1992).*

accomplishment of a mission. Orr reports that the particular insight from his research was the realization that the stochastic nature of combat has great implications for the exercise of command. He concludes that the normal practice of judging commanders on the basis of results they achieve in combat may be inappropriate because of the stochastic nature of combat and the actions of an enemy. *Is it possible for commanders to make faulty decisions yet emerge as winners, or for commanders to make correct decisions yet come out losers? What are the implications of this for command and control?*

In the chapter from *Concept*, the Soviet writers discuss an organizational decision as a form of preparation for action. They define the elements of an organization as its structure (scheme of relationships) and the internal distribution of its functions (information, management, action). Note that in their descriptions, the information flow characteristics dominate, rather than the authority relationships. They identify the following properties of a good organization:

- Ability to react to change (operational capability),
- Controllability (degree of centralization), autonomy, and
- Viability (after partial destruction).

The authors propose three logical ways for making organizational decisions:

- Modeling (to estimate cost and effectiveness),
- Evolution (from an existing organization), and
- Synthesis (formulating the tasks and defining the operating conditions).

If these three methods for making organizational decisions seem too abstract and therefore inapplicable, what practical methods would you propose in their place?

Readings

Case Studies

van Creveld. Chapter 3, "The Revolution in Strategy."

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Required Readings

King, E. J. "Exercise of Command." CINCLANT SERIALS 053 and 0328 of January 21, 1941 and April 22, 1941. Reprinted in Julius A. Furer. *Administration of the Navy Department in World War II*, Appendix I. Washington, DC: U.S. Government Printing Office, 1959.

Orr. Chapter III, "Command of the Combat Operations Process."

Druzhinin, V. V. and Kontorov, D. S. "Organizational Decisions," Chapter 4, *Concept, Algorithm, Decision: Decision Making and Automation* (USAF translation). Moscow: 1972.

Supplementary Readings on Organizational Decisions

Secretary of Defense. "Command, Control, Communications (C^3), and Space," Appendix K of *Conduct of the Persian Gulf War: Final Report to Congress*. Washington, DC, April 1992. [The first half of this report (pages K-1 through K-25) describe many of the organizational decisions made to support the Gulf War. It is noteworthy that half of the SECDEF's report on command and control is devoted to the resolution of organizational issues and wiring diagrams.]

Cushman, John H. "Ocean Ventured, Something Gained." U.S. Naval Institute *Proceedings*, September 1992, pp. 83-88. [Description of the command arrangements for Ocean Venture 92, a major joint exercise conducted under Commander in Chief, U.S. Atlantic Command. The exercise scenario involved crisis action planning and a forcible entry assault. During the exercise, the

commander, naval forces operated from a mobile command center ashore, within walking distance of that for the joint task force commander. The exercise left several organizational issues that require continued study. Cushman emphasizes that a joint commander may organize for combat in any way that will best accomplish the mission, but he is concerned that this normally means using service components. On the other hand, Cushman sees the joint task force commander acting as a service commander with additional joint responsibilities, instead of acting as a truly joint commander *without* service responsibilities (having transferred them to a service deputy. He would have had the deputy "run the fight," a job that the theater commander might have expected the joint task force commander to do.]

Winnefeld, James A. and Johnson, Dana J. *Command and Control of Joint Air Operations: Some Lessons Learned from Four Case Studies of an Enduring Issue*. Santa Monica, CA: RAND, 1991. AS 36.R281, no. 4045. [Case studies about the command and control of joint air operations based on the battle experiences of Midway, the Solomons, Korea, and Vietnam.]

Griffin, Gary B. *The Directed Telescope: A Traditional Element of Effective Command*. Fort Leavenworth, KA: Combat Studies Institute, 1991. [Griffin explores the use of what van Creveld calls the "directed telescope" through history, particularly during the Civil War and the two World Wars. Griffin concludes that some of the lessons of the past will apply as well in the future.]

Allard, C. Kenneth. "The Quest for Unity of Command," Chapter 4, *Command, Control, and the Common Defense*. New Haven, CT: Yale University Press, 1990. [In this chapter, Allard traces the development of the organizational principles followed by each of the Services from the end of World War I through World War II to the passage of the National Security Act of 1947. He describes how the development of air power (in the inter-war years and in World War II) and the establishment of the joint chiefs of staff and of joint theater commanders (during that war) was perceived by the different Services. He discusses attempts to reconcile hierarchical organizational principles favored by the Army with

a horizontal organizational structure that emphasized decentralization favored by the Navy.]

Kronenberg, Philip S. "Command and Control as a Theory of Interorganizational Design." *Defense Analysis*, Vol. 4, No. 3, pp. 229-252, September 1988. [Kronenberg believes that the tough challenges in command and control derive from attempts to control clusters of organizations, acting in ambiguous situations. Thus he feels we should be concerned with command and control not primarily within a single organizations, but across multiple organizations. He surveys the general literature on research into the dynamics of interorganizational systems as well as into the style of leadership that is successful in them. He seems attracted to the idea that efforts to "control" achieve only marginal effect.]

Deane, Michael. "Current Soviet Philosophy of Command and Control." *Defense Analysis*, Vol. 4, No. 3, September 1988, pp. 287-306. [An article on the historical evolution in the Soviet philosophy of command and control from 1917 through 1988 (when the article was written). Deane describes the slow (and often resisted) movement toward decentralization, and how changes in Soviet military philosophy became reflected in changes in their command structure. Some of the measures adopted by this superpower were the same as those adopted by the U.S., but some were not, and it is useful to appreciate the factors that made the difference.]

U.S. Statutes. "Combatant Commands" Part B of Title II, "Military Advice and Command Functions," *The Goldwater-Nichols Department of Defense Reorganization Act of 1986*. Public Law 99-433. U.S. Government Printing Office, Washington: 1986. [Prescribes the procedures for creating unified and specified combatant commands, and for assigning forces to them, and spells out in detail some of the specific command functions of the commanders of combatant commands.]

Joint Chiefs of Staff. "Command and Organization," Section II, Chapter 3, "Principles Governing Unified Direction of Forces," *Unified Action Armed Forces* (Joint Pub 0-2). pp. 3-1 to 3-36. [Chapter 3 declares that "Sound command organization should

provide for unity of effort, centralized direction, decentralized execution, common doctrine, and interoperability," and sets out the principles of command and organization currently prescribed to achieve the "unity of effort" required for effective use of military power.]

Cardwell, Thomas A. *Command Structure for Theater Warfare: The Quest for Unity of Command.* Maxwell AFB, AL: Air University Press, 1984. [This pre-Goldwater–Nichols analysis of theater command structures is an examination of both the experiences in World War II, Korea, and Vietnam, and the doctrinal views that each of the Services derived from their experiences.]

Barnard, Chester I. "The Theory of Authority." Chapter XII, *The Functions of the Executive.* Cambridge, MA: Harvard University Press, 1951. [Barnard argues that the exercise of authority is dependent primarily on whether directives are actually accepted and acted upon by the persons to whom they are addressed for action, and that the assent of subordinates to an order is dependent on their understanding it and believing it to be consistent with the general purpose of the organization.]

Clausewitz, Carl von. "The Army Order of Battle." Book Five, Chapter Five, *On War.* (1832) Princeton, NJ: Princeton University Press, 1976. [Considers the issue of how many subunits ought to report directly to one commander, as well as the effect of the length of the chain of command. Noting that a long chain of command results in a lessening of the vigor of a commander's orders and in a diminution of his personal power, Clausewitz nevertheless warns against subdividing an organization into so many parts that confusion results. He concludes that the appropriate number of subunits is four, or at most five.]

SESSION 4
Operational Decisions / Decision Aids

An admiral is given no time for calm reflection. He draws, in swift minutes, the conclusions that determine sea-power and affect the fates of nations. Surprise, astonishment, shock are only part of the problem.

Gibson and Harper, *The Riddle of Jutland*

Without the stress and the strain and the limit on time, nobody can actually duplicate the strain that a commander is under in making a decision.

Arleigh Burke, quoted in *Battle Report*

When choices must be made with unavoidably inadequate information, choose the best available and then watch to see whether future solutions appear faster than future problems. If so, the choice was at least adequate. If not, go back and choose again.

Eberhardt Rechtin in *Systems Architecting*

Focus

This session is devoted to consideration of the decisions that commanders make about what actions their forces are to take, and about the command and control processes that support these decisions.

Operational Decisions

While information decisions require resolution of uncertainties about events that are happening currently, operational decisions—the decisions about which course of action to adopt—have to be made in the face of uncertainties about *future* events. Like other decisions, an operational decision is actually an hypothesis: in this case, that the selected course of action is the most effective one to pursue. So, in addition to the uncertainties about the situation (including which course of action the opponent is about to adopt), there are also uncertainties about the outcomes that would result from the interactions between the courses of action open to a commander and those available to an opponent. The interaction that will actually occur depends on decisions taken by a number of commanders on both sides.

Furthermore, while operational decisions include the classic choices about what is to be accomplished and by whom, such decisions also need to take into account the imposition of outer limits on the use of force, usually received in the form of Rules of Engagement.

Tactical commanders in particular make their decisions under considerable stress. For a sense of the attitudes of tactical decision makers, read what Commodore Arleigh Burke (later Chief of Naval Operations) said in 1945 when describing his experiences as a destroyer squadron commander in the Solomons Campaign of 1943 and early 1944. During this period his squadron participated in a remarkable variety of combat operations, including the Battle of Cape St. George, which has been termed "the almost perfect surface action":

> We didn't much care about regulations by this time, nor did we care what people thought of us. We felt that if we did the job the best we could, and the way we wanted to do it, that if somebody didn't like it, well, they wouldn't like it. Apparently they did because we still stayed there.
>
> In any case, as it happens to so many people who have been in battles for a long time, their ideas of what is important change rapidly. Things that used to be very important were completely unimportant now. Good food was important, a glass of beer was important, what your

> shipmates thought of you was important, but what was written down on a piece of paper, or what somebody who was not fighting thought about how you were fighting, that was completely unimportant. He didn't know what he was talking about, we knew, and it was obvious from some of the letters, too, although nobody had criticized us. But we could read criticism about other people's action, and we commenced to believe that it took a combat man to analyze another combat man's action, and even then it can't be done, because nothing can ever be completely written in action. The reasons why a commander made the decision that he did make is probably obscured.
>
> I've tried keeping logs on the bridge, keeping a yeoman to write down all the reasons why I was going to do a certain thing, but then when the stress came I would probably think of a half dozen reasons very quickly. The yeoman would perhaps be asleep and I would hate to wake him up and I'd let it go, or perhaps he didn't even have time to write it down. In any case I made the decision, hoped it was right, but I never recorded all the reasons why I did make or why I did not make some other decision. The same thing is true with everybody, that without the stress and the strain and the limit on time, nobody can actually duplicate the strain that a commander is under in making a decision. Consequently it's a brave man, or an incautious one, who criticizes another man for the action which he took in battle unless it is obviously an error caused by lack of character.[1]

The "technical and tactical competence" of commanders is tested by the making of operational decisions. Of the many skills that need to be brought to bear—and are best developed by experience in command and in combat—a few are closely related to command and control:

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[1] *Narrated by Commodore Arleigh A. Burke, USN, "Destroyers, Strikes, Kavieng, Rabaul, etc. DesDiv 45 and 46; DesRon 23." Recorded: 8 August 1945, Microfilm No. 411-III, Arleigh Burke Papers, Naval Historical Center, Washington, DC, p. 15. Quoted in part in* Battle Report, *Vol. 4, "The End of an Empire," Karig, Walter C., Farrar and Rinehart, New York: 1948, pp. 70-71.*

- The ability to communicate clearly, concisely, and effectively, and the willingness to rely on a minimum of written directives;
- The ability to impart to subordinates a sense of purpose and a determination to succeed;
- The ability to appreciate the way that subordinate commanders (and superior commanders) are visualizing the situation;
- The ability to estimate the time it will take for decisions to be implemented, including how long before subordinate commanders receive and understand changes in orders and how long before new orders begin to be executed;
- The ability to foresee how much disruption would be caused by changing an order;
- The ability to estimate when reports ought to be received, so that the failure of a report to arrive will raise the question as to whether or not the operation is achieving its objective; and
- The ability to minimize confusion within friendly forces while promoting confusion in the minds of an enemy.

The command and control process is often seen as closely linked to events as they happen, and therefore somehow different from the classic military planning process, which appears to operate along a longer time line. In fact, the logic of the military planning process is the logic of the command and control process, and its phases are steps in that process:

- Development of a commander's estimate: to choose a course of action,
- Development of a plan to carry out the course of action: to identify the organization and the tasks to be assigned,
- Promulgation of a directive: to execute the plan, and then
- Supervision of the planned action: to adjust the directive as needed.

In the military planning process, the classic logic for the making of operational decisions is the Commander's Estimate of the Situation. The first steps of the estimate are to analyze the mission

assigned and to identify the key considerations that will affect the choice of a course of action. The middle steps require identification of alternative courses of action open to the commander and those open to the opponent. The final steps involve predicting outcomes of all possible interactions between own courses of action and those of the enemy, and then comparing advantages and disadvantages of each alternative course of action. The estimate lends itself to a matrix display that lists alternative own courses of action down the side and alternative enemy courses of action across the top.

The art of making operational decisions can be summarized by describing the process as the one that results in decisions that are at once suitable, feasible, and acceptable (the "tests" used during the development of an estimate). A course of action is "suitable" if its successful execution will result in accomplishment of the mission; it is "feasible" if it can be accomplished with the means available and in the face of the opposition expected; and it is "acceptable" if its cost (or losses incurred) do not exceed the value of the objective gained (or some other threshold established in the mission).

The real-time aspect of command and control is most associated with the final phase of the planning process: the supervision of the planned action. The key command decision during the supervision phase is whether or not to change directives already promulgated. Change may be prudent, either because the course of action needs to be adjusted because of unexpected events, or because the situation is so fundamentally changed that it has become necessary to revisit and revise the estimate of the situation. Yet a commander normally decides to make a change only when the presumed advantage of changing the course of action exceeds the relatively certain cost of making such a change while an action is in progress.

In the era prior to the introduction of reliable long-distance communications and efficient data processing and display, commanders anticipating that their forces might encounter a range of situations, wrote their orders with contingency courses of action, and worded their objectives at a level high enough that on-scene commanders could adjust their actions to cope with the unexpected. One of the unfortunate effects of increasingly capable C^4 systems has been to encourage commanders to feel that there is less need either for flexible orders or for the intensive planning that produced them. Thus, modern C^4 systems, instead of enhancing the classic military planning process, seem to have become a substitute for it.

Decision Aids

Increasing attention is being paid to providing commanders with decision aids to assist them and their staffs. At present, decision aids are most often used to perform the many calculations necessary to optimize the use of own forces, calculations that can now be made with a saving of time and/or people, or that previously were not even undertaken. Decision aids appear to show most promise for simple situations that can be defined in terms of well-understood physical principles and parameters. For complex situations that can be described and measured only in qualitative terms or that involve physical factors that are heavily judgmental, calculations of outcomes are at best imprecise, so should be treated with great skepticism and their underlying assumptions carefully examined.

While the outcomes of engagements flow from the nexus of decisions by the many commanders on both sides, the alternatives chosen by each commander will hinge on an evaluation of the *suitability*, *feasibility*, and *acceptability* of each course of action under consideration—whether it would accomplish the mission, whether the means are available to carry it out in the face of expected opposition, and whether the expected gains would outweigh expected losses. Of these three tests, the second one, for feasibility, seems to be most amenable to assistance by decision aids, but aids have been developed to assist in applying the other two tests as well.

One of the origins of decision aiding is the discipline of operations analysis which began in World War II to assist commanders in making better operational and tactical decisions. The scientists in the field were not required to optimize—to make the *best* decisions. Their goal was to shed enough light on a particular problem so that commanders on the spot could make some significant improvements in tactics or hardware. Typically, each problem was solved as it arose; the identification of patterns and techniques that formed the science of operations research came later. The scientists who pioneered operations analysis were effective because they did not carry the burden of *conducting* operations. The wartime operations analysts did not have to be concerned with predicting future battle outcomes, except in the sense that they would conclude that "if you make such and such a change, you will probably generate substantially more detections, or achieve substantially more kills."

These analysts were successful, first, because they could concentrate on *observing* the operations; second, because they were able to recognize patterns in dynamic interactions, to identify the significant and measurable aspects of the problem, and to gather the right data about them; and third, because they were accustomed to synthesizing what they had observed in some easily communicated form, either a statistical display or a very simple mathematical model, by which they could share their understanding of what was happening.

Modern computer power has opened the possibility of augmenting, assisting, and supplementing the decision process of commanders by synthesizing for display the information on decision alternatives. Displays of information have proved useful for alternatives like the allocation of search effort, the routing of attacks to minimize attrition, or the timing of the launch of interceptor aircraft. Even though decision aids are becoming more sophisticated, their outputs should be thought of as limited: not as predicted outcomes, but as assistance in making better decisions. Such limitation are *inherent*, and would exist even if the decision aid literally emulated nature. At their most elegant and comprehensive, decision aids such as a computerized war gaming system are able to play back some "if-then" statements: "if *this* set of *a priori* conditions holds in an engagement, then *that* will be the result." Yet even the rehearsal amphibious landings in World War II would have to be called poor predictors of what later happened during the actual assault landings. Nevertheless, rehearsal landings were important then and modern decision aids are becoming important today. Like the analyst of World War II the modern decision aid depends for its functioning on data and on rules, and depends for its utility on the relevance and accuracy of those data and rules. Commanders are likely to rely on decision aids only to the extent that they are persuaded of the strengths yet understand the limits of this modern electronic analyst.

A decision aid that predicts the outcome of an engagement might be like the computer programs that assess battle damage for war games. Such programs take into account the many probabilities: of detection, of correct classification, of weapon component reliability, and of other variables, and transform them—by rolling a die or, more commonly, by reference to a random-number table—into discrete events, so that the play of the game can continue. For the results to

be credible, the probabilities ought to be consistent with historic experience, yet events are binary; they either happen or they do not.

A commander about to choose a course of action also needs to consider how its execution will be viewed by an enemy. But creating a decision aid to assist in making judgments about how an enemy will view a course of action and respond to it would not only be difficult, but that particular judgement might be the critical one in a situation where inadvertent escalation is to be avoided, or where the objective of the operation is to influence the enemy commander to act in a particular way.

A commander would like to make operational decisions that prove more effective than the decisions being made concurrently by an opponent. Therefore, it might be tempting to develop some master decision aid that could convert the many lower-level probabilities into a single probability of a higher order—into a probability of mission success. Such a master decision aid will never exist, nor will any decision aid ever serve to absolve a commander from carrying out an *ordered* operation.

Commentary on the Case Study and Readings

In his chapter on mid-nineteenth century warfare, van Creveld describes the Prussian command system and contrasts it with Napoleon's. Both Moltke and Napoleon favored decentralization and employed directed telescopes, but Moltke emphasized greater peacetime planning for mobilization and deployment, while noting that no plan survives contact with the enemy. Moltke attempted to create flexibility by balancing independence with control. *Could Moltke's philosophy form the basis for an effective command and control policy today?*

Richardson describes the classic operational problem: the selection of targets. His description highlights the need to focus on how one's opponent functions and on his weaknesses. Richardson also emphasizes the need to bridge any gap that might exist between the intelligence and the operations portions of the staff. *What are the implications of this "bridging the gap" for staff organization? for command center design?*

Herres (then Commander-in-Chief of the U.S. Space Command [CINCSPACE], later Vice Chairman), describes command and control as viewed by a CINC, with particular emphasis on how a CINC

develops plans and makes decisions. The key words seem to be "what-ifs," "options," and "dynamic little circles."

Wohl examines the environment for making decisions about the employment of tactical air forces (in a NATO vs. Warsaw Pact environment). He describes the structure of the tactical decision-making process and then develops a paradigm to represent it. His Stimulus-Hypothesis-Option-Response (SHOR) paradigm clearly distinguishes the information decision (hypothesis) from the operational decision (option). After considering the kinds of human errors often found in decision making, he surveys the literature on behavior under stress in order to identify the various ways that humans attempt to cope with stressful situations. After noting for decision aids some of the implications of these different coping patterns, he is critical of the decision aids that were being developed at the time he wrote his paper (1981) as failing to address the central problems—generating and assessing hypotheses about the situation and about options for action. *Are Wohl's criticisms still valid today? Do his conclusions, drawn from a study of the "battle management" structure for a major war, apply as well to smaller wars? Do you agree with Wohl that decision aids should be made adaptive to the "style" of the decision maker?*

In his fourth chapter, Orr describes the two-sided nature of the military problem. Throughout this chapter he reminds us that each side has to provide for similar command functions, and therefore that the command systems on each side are subject to attack. Using the terminology he has previously developed, Orr describes his "military problem solving process model" as a five-stage process:

- Determine the desired power distribution (sources of power),
- Determine the current situation,
- Determine and evaluate possible actions,
- Select a plan, and
- Execute the plan.

Does Orr's military problem-solving process model really differ from the classic military planning process?

Readings

Case Study

van Creveld. Chapter 4, "Railroads, Rifles, and Wires."

Required Readings

Richardson, David C., "The Uses of Intelligence," in Coakley, pp. 305-306.

Herres, Robert T., "A CINC's View of Defense Organization," in Coakley, pp. 337-338.

Wohl, Joseph G. "Force Management Decision Requirements for Air Force Tactical Command and Control," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-11 No. 9, September 1981.

Orr. Chapter IV, "Effective Command of Combat Operations."

Supplementary Readings on Operational Decisions

Sage, Andrew P. "Human Information Processing Principles for Command and Control," *Principles of Command and Control*, pp. 54-74 (1987). [Summarizes a great deal of the current theory about human decision making and information processing. Sage characterizes human decision making as having three stages *prior* to the selection of the preferred option—formulation, analysis, interpretation—and three stages *following* that selection—planning, prioritization, description. Sage concludes that the first requirement for an effective C^4 system is to understand the user requirements and leadership characteristics, that the second requirement is to understand how the user's capabilities can be enhanced by appropriate support, and the third requirement is to design C^4 systems hardware and software to provide that support.]

Weissinger-Baylon. "Garbage Can Decision Processes in Naval Warfare," Chapter 3, *Ambiguity and Command*. Marshfield, MA: Pitman Publishing, 1986. pp. 36-52. [This chapter from a book

on the "garbage can" theory of decision making describes the author's observations on the way that flag offers make decisions during war games. He concludes that the "organized anarchies" and the ambiguities of technology, preference, and participation (postulated by the "garbage can" school) occur in naval settings and at least partially describe the conditions of combat decision making experienced by senior naval commanders. In what may be a paradigm for the relationship between the development of plans and the application of command and control, the author describes the "boxcar effect": that in the procurement world. That effect postulates that the components for systems planned for over many years always seem to be diverted at the last minute (their boxcars being redirected) to be used for different systems, whose unanticipated requirements are now urgent. He concludes that the planning for some systems is useful only if they can be applied to satisfying unplanned for requirements.]

Hughes, Wayne P., Jr. "Garbage Cans at Sea," *Ambiguity and Command*, pp. 249-257 (1986). [Does the "garbage can" model apply to decision making in the Navy? Hughes concludes that while in peacetime, some of the "garbage can" conditions (unclear goals, poorly defined operating procedures) may exist, in wartime these conditions are corrected and fade away, although not immediately: it may take a matter of months.]

Druzhinin. Chapter 5, "Operational Decisions." [Defines organizational decisions as choices about the method for conducting combat operations, noting the two-sided nature of combat, and taking into account the risks involved. The chapter contrasts the way men and computers apply mixed strategies.]

Barnard, Chester I. "The Environment of Decision." Chapter XIII, *The Functions of the Executive*. Cambridge, MA: Harvard University Press, 1951. [Distinguishes the decision-making process in organizations from the process used by people as individuals, pointing out that whereas the evidence of decisions is usually found in the orders issued, the decisions themselves occur in the interplay between purpose and environment.]

Clausewitz, Carl von. "Friction in War." Book One, Chapter Seven, *On War.* Princeton, NJ: Princeton University Press, 1976. [Clausewitz terms those factors that lower the general level of performance as "friction," although he does not suggest that the best general is the one who takes friction to heart. Clausewitz might, however, have suggested that the command and control process—particularly the supervision of the planned action—plays a role in detecting friction and reducing it.]

Supplementary Readings on Decision Aids

Dillard, Robin A. "Using Data Quality Measures in Decision-Making Algorithms," *IEEE Expert: Intelligent Systems & Their Applications*, December 1992. pp. 63-72. [Like many articles about artificial intelligence, this one has a few formulas. Its virtue is that it concerns the decision by the commanding officer, USS VINCENNES to shoot down the Iranian airbus. The issue being studied is which of four algorithms for decision making would be useful in situations like this one, where there were several mutually exclusive hypotheses and some reported facts and measurements whose accuracy and quality are uncertain. The article is full of discussion about probabilities, but it provides some insight into the complexity of creating artificial intelligence systems and rules to assist commanding officers to deal with situations like the one that faced Captain Rogers.]

Andriole, Stephen J. "Leveraging Command and Control via Enhanced Command Decisionmaking: Prospects for a Behavioral Theory of Command and Control." *Defense Analysis*, Vol. 4, No. 3, pp. 253-265, September 1988. [Andriole's article is an attempt to get systems designers to stop treating commanders as proverbial "black boxes." He blames the immature state of command and control theory on the lack of emphasis on command decision making, which he feels is the essence of the command and control process. He urges more and better research on understanding human information processing and on establishing which decision making functions are best performed by humans, which by machines, and which by humans aided by machines. He notes that the Soviets had gone to great lengths to

train their commanders in mathematical decision theory, cybernetics, and operations research.]

Hopple, Gerald W. "An Assessment of the State-of-the-Art of Advanced Analytical Methodologies for C^3 Decision Support," *Principles of Command and Control*, pp. 343-369 (1987). [Hopple surveys the various techniques and methodologies for making decisions, in order to help anyone embarking on developing a computer-aided system to appreciate the variety of analytical tools available for adoption.]

Shumaker, Randall P. and Franklin, Jude. "Artificial Intelligence in Military Applications," *Principles of Command and Control*, pp. 319-336 (1986). [Both a tutorial on artificial intelligence and a description of some projects attempting to harness AI.]

Andriole, Stephen J. et al., "Intelligent Aids for Tactical Planning," *Principles of Command and Control*, pp. 194-212 (1986). [Descriptions of two attempts to use computers to aid the military planning process: the first, TACPLAN, acts as a simple assistant to the planner, asking questions and recording answers, and comparing them to a set of rules in the knowledge base; the second, INTACVAL, uses a different knowledge base, one that identifies the attributes and value of objects, that generates options for review by the planner, and that uses graphic displays with overlays.]

Thomas, Clayton J. "Models and Wartime Operations Research." *Military Modeling*. Alexandria, VA: Military Operations Research Society, 1984. [This chapter introduces the rest of a book that contains descriptions of models for different forms of warfare and for different aspects of warfare. It is really a primer on the uses and limitations of models and the methods of operations research.]

SESSION 5
C^2 *in Combat / Telecommunications*

The art of war is simple enough. Find out where your enemy is. Get at him as soon as you can. Strike at him as hard as you can and as often as you can, and keep moving on.

Ulysses S. Grant

Nowadays luck only stays with the good general who has a good system of command and control.

Richard Simpkin, *Race to the Swift*

The detailed knowledge of a few individual engagements is more useful than the general knowledge of a great many campaigns.

Clausewitz, *Principles of War*

Operation Desert Storm demonstrated that tactical communications are still plagued by incompatibilities and technical limitations. At CENTCOM corps and wing levels, a significant portion of the war was conducted over commercial telephone lines because of the volume and compatibility limitations of the military communications system.... Communications were worse in the field.... Multiservice strike packages were difficult or impossible to assemble because various aircraft communicated in different ways over secure voice channels.

Les Aspin and William Dickinson,
Defense for a New Era: Lessons of the Persian Gulf War

Focus

How have successful commanders in the past exercised their command? This session will review how the command and control process has functioned in combat, will consider many student case studies on the subject, and will explore the capabilities and vulnerabilities of modern telecommunications systems.

Command and Control in Combat

Any attempt to apply the lessons of history to modern problems raises two questions:

- What, in fact, *are* the lessons of history? and
- To what extent do they apply today?

The methods by which successful commanders have exercised their command during wartime battles has often been obscured by the attention focused on their strategy and tactics. This may be changing; writers now seem more likely to consider command "style" or clarity of expression as characteristics worthy of consideration and comment. This new interest extends not only to the ways that the "great captains" made decisions themselves, but also to the ways they used doctrine to influence the decisions will be made by their subordinate commanders. Doctrine that is developed during peacetime has often been devised in a way that increases the "control" of those writing the doctrine, but after the war has begun, and the forces have been in action, doctrine usually becomes modified in a way that increases the autonomy of commanders in the field. During this course, we have already read about the command styles of a number of successful commanders. *Have you detected any common thread that might suggest some principles for success in command?*

Telecommunications

The need for reliable communications in military operations appears to be increasing. Modern combat forces are equipped with weapons systems whose effective employment depends on central coordination, yet they need to disperse in order to survive the lethal power of similar weapons possessed by forces on the other side. Thus, modern

military operations though centrally controlled, take place over very large battlefields. While operations over extended areas by naval and air forces are commonplace, even modern ground combat troops have begun to operate over large areas. NATO doctrine, for example, dispersed ground troops far more thinly over the battlefield (15 men per square kilometer) than was done only eighty years ago (404 men per square kilometer). Furthermore, while we usually think of technology as *solving* problems, improved technology is now *creating* problems for telecommunications, whose requirements are now being driven by the increase in computer speeds (about 30 percent per year) and the increasing availability and granularity of graphics. In addition to the factors of dispersion and technology noted above, some telecommunications requirements continue to be driven by human *curiosity*.

Successful combat operations today have increasingly become dependent on electronic methods of communications to sustain personal relationships even though there is some risk that electronic methods diminish the impact of personal leadership. In an information-flow sense, the world seems to have shrunk; modern telecommunications has made it possible for people in their living rooms to view in full color an engagement in the Falklands, Panama, or the Persian Gulf. Modern telecommunications is overcoming the physical distances that separate decision makers from each other and from the sources of information on which they rely to make their decisions. Even though the rate of change of events is usually greatest at the scene of action, the opportunity to readjust decisions is distributed throughout the chain of command.

While telecommunications is usually characterized by its electrical attributes—bandwidth, data rate, throughput, or error rate—its value to command and control derives from its ability to establish "connectivity" not only between commanders related by the chain of command, but between their staffs, as well as between "coordinators' and the commanders being coordinated, between supporting commanders and the commanders they are supporting, between sensors and the commanders who need the information, and between commanders and forces that need to cooperate with (and not surprise) each other.

The classic description of a communications circuit was formulated in 1948 by C.R. Shannon in his seminal article, "A Mathematical Theory of Communications." He identified six

significant elements. He pointed out that in addition to a "transmitter" and a "receiver," it is necessary to have an "information source" to provide the information to be transmitted, and a "destination" for the information received by the receiver. He also identified the information "channel" between the transmitter and receiver as an element, through which the transmitted signal must pass and which itself imposes some limitations on the rate of transmission. Finally, he identified a "noise source" that introduces noise into the information channel, adding an additional task for the receiver: to distinguish effectively between the transmitted signal and the noise.

To understand the telecommunications process, it is necessary to appreciate two of its basic characteristics: it is symmetrical and it is arbitrary. If ideas are to move reliably from the mind of one commander to the mind of another, the transformations that are undertaken on the sending (transmitting) side have to be matched on the receiving side, and they have to be matched exactly. Everything that has been done at the transmitting end must be undone at the receiving end: every analog-to-digital conversion at the transmitting end needs to be matched by a corresponding digital-to-analog conversion at the other end, every encryption by a decryption, and every modulation by a demodulation. Therefore the planning necessary to achieve an effective telecommunications path is detailed and unforgiving: any unmatched step will result in communications problems or failure. It should be clear, then, that because there are alternative methods available for performing each of the communications steps, the dominant requirement when establishing a telecommunications path is not necessarily to optimize the process but to standardize it at each end. More important than doing things the *best* way is doing them the *same* way, which is the objective of programs to achieve joint interoperability.

This course is not a technical one, nor does it contend that commanders and their staffs need to be fully conversant with the technical details of telecommunications systems. Nevertheless a commander can expect that when communications officers explain telecommunications performance, they have assumed that their commander understands a few fundamental ideas about telecommunications, and that communications officers will be generous in making such assumptions so as to avoid insulting their boss.

These fundamental ideas include the concept of a wave form, the differences between analog and digital, and (for operations dependent on radio) the differences in transmission characteristics in the various radio frequency bands. Such considerations affect the "costs" of communicating—costs in terms of equipment, people, delays, and errors—which may be quite different from the "value" to the commander of transmitting or receiving the information itself. Communications officers will tend to think in terms of the "costs," while commanders will think in terms of the "value" of communications. Communications officers will, for example, be conscious that television transmission requires one thousand times the bandwidth used by a radio signal, while commanders will discount such considerations and focus on the value of a video picture.

The term "wave form" is used to denote the shape of the electrical signal (usually voltages as a function of time) that a transmitter generates, and then sends over a channel to be recognized and interpreted by a receiver. Wave forms convey information from source to destination. This concept is an important one when we come to consider "interoperability," because it emphasizes that although having the same equipment at each end may be useful, the important question is whether the receiving equipment will recognize the wave form of the signal generated by the transmitter.

The distinctions between "analog" and "digital" can become somewhat confusing, because these terms are used not only to characterize the form in which information exists at a source or as it is presented for transmission but also to characterize the form of the medium used for transmission. The human voice (whose frequency and intensity vary as a function of time) is an example of information in an analog form at its source, and which can without modification be transmitted by modulating either the amplitude or frequency of an analog radio signal.

Historically, the telephone network—an analog transmission system—was well matched to its information source—the human voice in analog form. Digital information, like the letters or numbers used in teletype machines, or data in computers, has to be converted prior to transmission over a telephone network into some analog form by the use of a modulator, whose conversions have to be matched in reverse at the receiving end by a demodulator. These modulator/demodulators (now generally called "modems") provide the conversion from analog to digital or from digital to analog.

Whenever analog signals are amplified, any accompanying noise is also amplified, but when digital signals are amplified, they can be reconstituted in their original form (without the noise). Because signals in digital form can be reconstructed with fidelity, the telecommunications industry has been converting analog information to a digital format for switching and (more recently) for transmission. Thus, for a variety of reasons, information is converted from one form to the other so that it matches the methods being used for transmission and switching. Increasingly, telecommunications systems are becoming digital systems, with the result that it is becoming immaterial (to the system) whether the "terminals" are humans, teletype machines, fax machines, or computers.

Encrypting the human voice for security reasons creates the need to convert from analog to digital for a different reason. High-quality cryptographic systems add a digital stream of cryptographic signals to a digital stream of information in order to produce a digital stream of encrypted information. Therefore, to provide cryptographic security for voice transmissions, it is necessary first to convert the human voice from its normal analog form to a digital form so that a digital key stream can be added to it for encryption. An encrypted digital stream can then either be sent over a digital transmission medium or converted back to an analog form for transmission over an analog transmission system. Thus, secure voice systems are often the most complex and costly parts of large-scale telecommunications systems. Note that each conversion on the transmit side must be matched exactly on the receive side. Even though conversions may be accomplished in a number of different ways, it is important that it be done the same way at both ends.

The propagation of radio waves is a function of their frequency—measured in hertz (cycles per second), kilohertz (thousands of cycles per second), megahertz (millions of cycles per second), or gigahertz (billions of cycles per second). Each radio frequency band has somewhat different transmission characteristics. As a general rule, the frequencies at the high end have directive characteristics like those we associate with the transmission of light, while the lower frequencies have bending characteristics somewhat like those we associate with the transmission of sound. Some frequencies in the middle range can also be refracted by discontinuities in the troposphere or ionosphere. Wavelengths are inversely related to frequencies (the product of wavelengths and frequencies

being equal to the speed of light). Thus the wavelength of the very low frequencies (VLF) used to transmit to submarines is on the order of ten miles, while the wavelength of a super high frequency (SHF) satellite circuit is on the order of an inch. The size of active antenna elements is directly related to the wavelength of the signal being transmitted or received. Recently there has been a trend toward "multi-spectrum" transmitters and receivers, which use the same box to operate at any frequency. This approach is achievable electronically, but the relationship between the size of efficient antennas and the radio frequencies being used still applies.

The "links" in a C^4 system are provided by telecommunications circuits, and to the extent that these circuits are radio circuits (including satellite or microwave relays), the links become subject to an enemy's electronic warfare (EW). Therefore, as modern combat has become dependent upon reliable radio communications, military forces have had to adopt operation security (OPSEC) measures in order to make the locating and identifying of transmitting stations more difficult. Conversely, to the extent that an enemy uses radio circuits, it becomes attractive to conduct electronic warfare (EW) operations to disrupt enemy communications networks at the time they are most essential, and to use communications intelligence (COMINT) operations to exploit an enemy's dependence on communications and to undermine whatever faith enemy military commanders may have in their own communications systems. Command and control and electronic warfare involve somewhat different considerations, but these considerations do converge when radio circuits are used, as they must be, to reach mobile platforms such as ships, tanks, and aircraft. Links that rely on wire or cable instead of radio, on the other hand, face vulnerabilities of physical destruction along their entire length.

Commentary on the Case Studies and the Readings

Admiral Nelson's great victories at the Nile, Copenhagen, and Trafalgar are often attributed to his superior tactics and to the readiness of his ships and men. Palmer points out that Nelson's command and control methods and "style" also contributed to these victories, and that such methods should be of more enduring interest to later generations of officers. The famous "Nelson Touch" included his personal leadership, and the deliberate sharing of his intentions

with his subordinate commanders. *Is there a place for the "band of brothers" approach to command and control today?*

World War I has provided the basis for a variety of lessons about warfare. Van Creveld describes how the senior commanders of that war had adopted the idea that warfare had become a science rather than an art, and how they sought to eliminate the disorder of warfare through exhaustive planning, strict timetables, and tight control. In effect, the management methods of the office, factory, and railroad were being applied to warfare. *Do you agree with van Creveld that methods that may have proved indispensable to the raising, deployment, and sustaining of armies, invited disaster when applied to the battlefield? If so, do we run any risks by using the same Joint Operation Planning and Execution System (JOPES) both for the employment of forces as well as for their mobilization, deployment, and sustainment?*

Van Creveld points out that while commanders desired positive control, their communications means to effect it were often lacking; commanders were therefore left with two alternatives:

- to undertake only those operations that could be closely controlled, or
- to plan operations that did not require close control.

Van Creveld asserts that during World War I, the British chose the former course, while the Germans chose the latter. The need for order and control has usually been justified by arguments emphasizing the desire to prevent waste and to mandate coordination, and by the assumption a commander-in-chief alone is in possession of all the facts. On the other hand, the case for fewer controls and lower decision thresholds is based on the desire for rapid, independent, and decisive action at all levels, for the exercise of initiative by subordinates, and for the achievement of lateral coordination and mutual support.

Van Creveld endorses Ludendorff's command style during the 1918 German offensive over Haig's during the 1916 British offensive. *To what extent did the German advance benefit from Ludendorff's approach to command and control? How does Ludendorff's assumption that tactics were more important than strategy affect his command and control style? Are the two*

alternative styles evident in other wars and battles? Are the contrasting styles evident today among the several Services?

Van Creveld believes that Ludendorff's use of directed telescopes enabled the German commanders to move with their troops. *Was this a significant factor in the German success?*

The interim report by the Secretary of Defense on the C^3 systems of U.S. and coalition forces during the Persian Gulf Conflict (Question 15) deserves to be read carefully. This interim report was superseded by a "final report" from the Secretary of Defense in April 1992, but the interim report is retained as a reading because it is fresher, more informative, and covers the issues more frankly. [The final report is listed as a supplementary reading for Sessions 3 and 7.]

It would be difficult enough to summarize in a few pages the operational and technical accomplishments and shortcomings of a wartime C^3 system that grew to ten thousand circuits, but it is nearly impossible to do so with complete accuracy in an unclassified document that has undoubtedly been staffed through organizations not eager to have their shortcomings highlighted.[1]

The general tone is one of accomplishment, even claiming for the C^3I system much of the success of Desert Storm. Yet despite the upbeat language, it is clear that greater attention will need to be paid to plans for developing theater infrastructures, to the integration of satellite transmission systems, to the rapid promulgation of a useful set of operating instructions, to improving both the inputs to and promulgation of air tasking orders, and to a greater measure of interoperability. While none of this should have been surprising, the authors of the report actually seem surprised that the operation succeeded despite the lack of "a single 'supreme' commander." The authors acknowledge that the C^3I system "evolved in capability as the deployment progressed," and that success depended both on "central management" (though they do not identify the central manager) and on the "many interfaces, intensive management, and substantial workarounds" that indeed have always characterized the creation of a command and control capability in fast-changing situations.

[1]For some frank comments on how the telecommunications systems of each Service (except the Navy) performed during the Gulf War, see the January 1992 issue of *IEEE Communications Magazine*, listed as the first supplementary reading on telecommunications.

Particularly noteworthy in this response to Question 15 are references to such factors as deep basing, to the Scud threat, and to the use of commercial equipment and systems. It will be interesting to hear whether this description of the performance of C^3I systems accords with the experience of those who actually participated, and if not, to speculate on why not.

In his summary chapter, Orr, relying on his earlier conclusions about the stochastic nature of combat, outlines what sort of C^3I system he feels best supports combat operations. *Do you agree with his conclusion that a distributed C^3I system, based on "problem definition, decomposition, and allocation" is the type best suited to the realities of warfare and the American character?*

Beaumont, in his introduction, is concerned that commanders may become too dependent on C^4 systems in peacetime, only to see them penetrated, disorganized, or destroyed in wartime. He is also concerned that such systems tend to centralize authority and weaken the chain of command. *Is Beaumont justified in his concern that experience with C^4 systems in peacetime is inadequate preparation for coping with their damage and destruction in wartime? If so, what could be done to enhance our capability to cope?*

In his Chapter 1, Beaumont traces the evolution of command and control, including the increased ability to communicate rapidly over great distances, the development of staff systems, and the employment of electronic warfare. (Some aspects of this evolution have already been described in more detail by van Creveld.) Beaumont notes the tendency of people to focus narrowly on the engineering aspects of specific systems and to have difficulty in developing an overall perspective of command and control. *Do you agree with him that this difficulty can be attributed to a general lack of interest in the general history of command and control or in the problems that arise between C^4 systems? Would this lack of perspective help to account for slow and often unsatisfactory acquisition of C^4 systems? At this point, what do you consider to be the main obstacle to the creation of a clear perspective of command and control?*

The examples in the Carter reading focus on communications during crisis situations as well as the communications systems that support nuclear forces, yet his descriptions of telecommunications technologies and of the threats to communications apply generally. Carter provides a good summary of information theory, and he

describes the characteristics of the various radio frequency bands, the vulnerabilities of radio communications, and some principles of cryptography. He also outlines the effects of nuclear explosions on electronic systems. As he points out at one point, "all these details are tedious but important." The reader should gain the general impression that communications by radio is difficult in any case, and can be made even more difficult by the efforts of a determined enemy to exploit or deny it. *If you were to advise an enemy about how to disrupt U.S. military communications, what would you suggest as the focus of attack?*

The 1991 article in *Scientific American* by Cerf is intended to be a tutorial on modern telecommunications systems. Cerf distinguishes between circuit-switching systems (like telephone systems) and packet-switching systems (like the networks used for transmitting messages). He then describes some existing and evolving protocols (for ethernet, for token systems, as examples) in packet-switching systems. To insure that a telecommunications system behaves the way that the originator of a call or message intends it to, such a system needs to provide for the transmission not only of the data or text but of the signalling (for circuit-switched systems) or the addresses (for packet-switched systems). Such signalling and addressing features are essential to the control of telecommunications systems. Cerf then introduces the seven-level hierarchy now being used in telecommunications architectures (to be explored further in Session 9). He explains the role of gateways as well as some options for achieving security: passwords, authentication, and cryptography. Although Cerf illustrates his article with examples from the commercial world, these technologies are applicable as well to military systems. *Do you agree with his assumption that the computer has already replaced the human caller or message writer as the driving factors in the establishment of requirements?*

Readings

Case Studies

Palmer, Michael A. "Lord Nelson: Master of Command." *Naval War College Review.* Winter 1988. pp. 105-115.

van Creveld. Chapter 5, "The Timetable War."

U.S. Secretary of Defense. "Command, Control, Communications, and Operational Security of the Coalition Forces as a Whole; and Command, Control, Communications, and Operational Security of the United States Forces," Question 15, *Conduct of the Persian Gulf Conflict: An Interim Report to Congress.* Washington, 1991.

Required Readings

Orr. Chapter V, "C^3I in Combat Operations."

Beaumont. Introduction, "An Overview of Command and Control," and Chapter 1, "The Historic Evolution of Command and Control."

Carter, Ashton B. "Communications Technologies and Vulnerabilities," *Managing Nuclear Operations.* pp. 217-282.

Cerf, Vinton G. "Networks," *Scientific American* September, 1991, pp. 72-81.

Supplementary Readings on Command and Control in Combat

Aspin, Les and Dickinson, William. *Defense for a New Era: Lessons of the Persian Gulf War.* Washington, DC: Govt. Print. Off., 1992. DS 79.72 A842 1992. [Basically a study report by the staff of the House Armed Services Committee. Of particular interest are the pages on command and control and on C^4 systems: "The Air Tasking Order," pp. 9-10, "Communications Hampered by Old, Incompatible Equipment," pp. 22-24, and "Goldwater–Nichols Played a Critical Role," pp. 41-42.]

Adam, John A. "Warfare in the Information Age," and Gibson, Tim. "The Digitized Drums of War," *IEEE Spectrum*, September 1991, pp. 26-33. [A description of the Gulf War with emphasis on how the employment of high-tech systems influenced its conduct.]

Keegan, John. "Wellington's Staff," "Wellington in Battle," "Observation and Sensation," "Grant's Staff," "Grant on Campaign," and "Grant the Fighter," *The Mask of Command.* New York: Viking, 1987, pp. 132-138, 145-163, and 194-229.

[Describes the techniques (and highly developed skills) used by Wellington and Grant as part of their command and control process.]

Reeves, W. Robert. "Soviet C^3: Theory and Practice," *Principles of Command and Control*, pp. 277-288. (1985) [Describes what the Soviets call "troop control," and concludes that the term is more comprehensive than our C^4 or even C^4I, because it includes navigation, electronic warfare, and cover and deception, which the Soviets incorporate into all phases of their operations.]

Gatchel, Theodore L. "Can a Battle be Lost in the Mind of the Commander?" *Naval War College Review*, January-February 1985, pp. 96-99. [A short but interesting account of the battle for Hill 107 during the German attack on Crete in May 1941. Gatchel contrasts the actions of the battalion commanders on each side, as their uncertainties mounted. He concludes that a commander's ability or inability to deal effectively with such uncertainties may decide the issue.]

Forester, Cecil Scott. *The General*. (1936) Penguin Books: 1972. [A classic novel that traces the career of a British Army officer, including duty as a general officer during the First World War.]

Marshall, Samuel Lyman Atweed. *Men Against Fire: The Problem of Battle Command in Future War*. Washington, DC: Infantry Journal, 1947.

Supplementary Readings on Telecommunications

IEEE Communications Magazine, January 1992, Vol. 30, No. 1. [Devoted to "The Role of Communications in Operation Desert Storm."]

Baker, Philip J., Jr. *Command and Control Mechanisms in the Chickamauga Campaign: The Union Experience*. Fort Leavenworth, KA: U.S. Army Command and General Staff College, 1989. [Examines the methods of communications available to General Rosecrans before and during the battle. Baker concludes that while Rosecrans did not use his

communications assets efficiently, this was not a key factor in the battle's outcome.]

Kahn, Robert E. "Networks for Advanced Computing," *Scientific American*. October 1987, pp. 136-143. [A tutorial on circuit-switching and packet-switching approaches to networking; describes different structures for local area networks and the architectural problems that have to be solved when interconnecting existing networks. Implicit in this paper is the assumption that the capacity of transmission systems will and should continue to expand.]

Stockdale, James B. "Communicating *Without* Technology," *Signal*, October 1979, pp. 26-32. [Admiral Stockdale describes the methods used by Americans as prisoners of war in Vietnam to communicate with each other. His description includes the main elements of any communications system: the code itself, the procedures for call-ups and receipts, and the problems of establishing initial contact. He concludes that communication is the connection of one brain to another, and he criticizes today's "overbuilt, overpriced systems that disgorge bales of unnecessary data."]

Shannon, C.E. "A Mathematical Theory of Communication," *Bell System Technical Journal*, Vol. 27, July 1948, pp. 379-423. [Twenty-five years after this article appeared, an editor was able to assert that "probably no single work in this century has more profoundly altered man's understanding of communications." The article became the basis for development of the disciplines now called "information theory" and "coding theory." Shannon defined a communications system as consisting of five elements: an information source that generates a message (in symbols), a transmitter that converts the symbols of the message into signals suitable for transmission, a channel for the transmission of signals from transmitter to receiver, a receiver that reconstructs the symbols of the message from the received signal, and a destination to which the receiver delivers the message. He points out that information can be passed a greater rate when some statistical information is known about the symbols used to convey the information at the source. This known statistical information

is termed "entropy" (which increases from zero when we are certain of every symbol in the message to a maximum when all possible symbols are equally likely). Entropy is also the average number of binary digits (bits) required per symbol. Shannon then introduces the idea that a signal in a channel is likely to be perturbed by noise during transmission so that the received signal is a function of both the transmitted signal and the noise. He then discusses some strategies for reducing to an arbitrarily small fraction the effect of the noise (strategies that later led to the development of "coding theory").]

SESSION 6

C^2 *During Crises / Computers*

No staffer can manage crises. Once a crisis starts you can bet your life that if you are the crisis manager's staffer, you will be kicked aside and all the principals...will take over and run it, and you might as well go home.

William Odom (1980), quoted in
C^3I: Issues of Command and Control

A business (like any organization) is constituted as a network of recurrent conversations. Computers are a tool for conducting the network of conversations.

Winograd and Flores,
Understanding Computers and Cognition

If computers and computer programs supposedly are getting easier to use, why are so many companies still making a nice living publishing books on how to use them?

Donald Norman, in *U.S. News & World Report*
November 23, 1992

Focus

In this session, we examine the command and control process as it has functioned during crises, and discuss student case studies on crisis situations. We also consider the role that computers play in command and control by assisting commanders to make decisions and to save time.

Command and Control During Crises

Since the mid-1960s the President as Commander-in-Chief has had an increasing capability to monitor developing situations on a timely basis and to communicate directly with field commanders. This has encouraged presidents to try to exercise control of events as they are happening, and has significantly modified their relationships with on-scene commanders. Prior to the introduction of new technologies during the 1960s and since, the Commander-in-Chief issued strategic direction in terms of general objectives that provided latitude for field commanders to determine the level of force and the choice of tactical methods. Today's Commander-in-Chief is able to influence tactical decisions more directly and to monitor progress on a minute-by-minute basis. Furthermore, the President has often had available to him current intelligence not necessarily available to the field commander, although provisions are increasingly being made to share national-level information with field commanders.

On-scene commanders and other commanders in the chain of command might react to the use of these increased abilities in a reasonable but unfortunate way. They might assume that when orders are received from higher authority directing specific actions by part of their force, the higher authority has somehow assumed responsibilities for detailed direction for the entire force. Yet commanders remain responsible for foreseeing danger to the survival and integrity of their forces, and for preventing hostile actions from jeopardizing their ability to accomplish the mission. In the International Rules of the Road intended to prevent collisions at sea, there is a "general prudential" rule that in effect instructs the masters of vessels to depart from the other rules if necessary in order to avoid immediate danger. This rule might be paraphrased to make clear that despite all the "help" commanders receive from higher authorities,

they continue to be responsible for the effectiveness and security of their commands. Such a paraphrased rule might read:

> In obeying and construing these orders, due regard shall be had to all threats to the survival and integrity of your command, and to any special circumstance which shall render a departure from these orders necessary in order to maintain your ability to accomplish your mission.

As a result of experiences with crises, Crisis Action Procedures have been developed that provide for the preparation of a commander's estimate by the theater commander who has been designated to be the supported commander, an estimate that includes consideration of operation plans previously prepared.

For joint operations, a crisis has been defined as:

> an incident or situation involving a threat to the United States, its territories, citizens, military forces, and possessions or vital interests that develops rapidly and creates a condition of such diplomatic, economic, political, or military importance that commitment of U.S. military forces and resources is contemplated to achieve national objectives.

Crisis situations put particular pressures on the command and control process. In most non-crisis operations, operational decisions usually respond to some varian of the question: should our carefully thought-out plan that is currently being executed be modified? In a crisis, both the modifications to the plan and the plan itself have to be developed in real time. Furthermore, both the information decisions and the operational decisions are being made for the first time, and some new organizational decisions often have to be made as well.

Although in many ways each crisis is unique, crisis participants often find that:

▾ The structure for decision making is either unclear or needs to be created, and an uncertainty may exist as to who is empowered make which decisions, so a

commander is required to make and promulgate some *ad hoc* organizational decisions;
- Decision makers often find themselves dependent initially on experts, but soon may learn to invoke increasing skepticism about expert advice, and to develop a real appreciation for hard-headed fact-finding skills to support their information decisions; and
- Decision makers learn that they may have to slow the velocity of decision making, by resisting pressures to make operational decisions immediately, without taking sufficient time to make deliberate information decisions or to apply some logical process to the making of operational decisions.

A crisis situation presents a large number of problems, all of which appear to require prompt resolution. Some of these have command and control implications. One such issue arises during the selection of forces. An operation may require execution of tasks whose scope and diversity are beyond the capabilities of any existing organization. Although the missing skills and equipment may be available from several separate organizations, it is possible that such units will seldom if ever have operated together. The question then arises whether it is better to pick the "best" units (an "all-star" team) from separate organizations and hope that the cohesion and teamwork needed for effective command and control can be created quickly during the operation, or better to select an existing organization that has some (but not all) of the capabilities required and then attach to it other organizations with the missing skills. *Which of these alternatives would you adopt? (Your answer may depend on how much you believe command and control contributes to success, and how long you believe it takes to achieve effective cooperation between forces unaccustomed to operating together.)*

In the many crises over the past forty-five years, command and control has been exercised in the Department of Defense under a wide variety of circumstances, with both success and failure. While the participants themselves may have learned a few lessons from these crises, their command and control experience is not as readily available as it should be for the education of those who will follow them and who could benefit from the prior experience. Efforts to identify "lessons learned" are useful, but most of these lessons relate

to equipment or procedural shortcomings that have now been corrected.

In order to understand the decision-making aspects of prior crises, most of us need to be able to view the crisis "from the inside" before being ready to accept some distilled "lesson learned" derived by someone else. To appreciate the environment in which specific decisions were made during past crises, it would be necessary to read the messages that were then available, understand what tasks and objectives were assigned, get a sense of the dominant uncertainties, and be able to distinguish what was known from what was unknown or at least unclear. Personal accounts (when they are available) by participants in an operation or crisis are useful up to a point, but they are usually intended to assure the listener or reader that the narrator wisely and systematically overcame all obstacles.

What is needed are some case studies that would recreate the decision-making environment of previous crises. The development of such case studies might require access to information still highly classified and likely to remain so, whose disclosure might result in a less than flattering portrait of the participants. In the absence of authoritative case studies, therefore, participants in future crises may have only their own mistakes to learn from. Still, there is a growing unclassified literature on some of these crises, although the emphasis is often on what happened rather than on what decisions were made, and when. *What kind of case studies or exercises do you feel would help future commanders and staff officers to benefit from the experience of specific situations from the recent past?*

Computers

There is now considerable experience using computers to maintain the status and to some extent the location of own forces, but whether this tremendous reporting and computing effort has been indeed useful to the makers of decisions is not really clear. The role of computers in support of command and control is still evolving. Apart from their extensive use in sensor and communications networks and in the correlation, filtering, and analysis of information (particularly about an enemy), computers are used to support the command and control process in the following ways:

- To maintain and display the continually updated status of own and friendly forces,
- To maintain and display the continually updated capabilities of the enemy,
- To optimize deployment plans and to test them for transportation feasibility,
  to estimate possible outcomes of potential military engagements.

The exercise of authority over commanders at the next lower echelon is often based on status reports from units several echelons further down. Because it is possible that such information will have been reported unreliably or have changed since the latest report was received, queries are sometimes sent to verify information at the last minute. Reports are most likely to be accurate when the reporting system has been devised in a way that provides incentives for reporting commanders to make sure their reports are accurate and timely, yet incentives for accurate reporting are sometimes overlooked in the design of reporting systems. An alternative method of obtaining accurate (though not necessarily relevant) information in reports is to couple the sensor or weapons system that measures or produces the raw information directly with some automatic reporting device, but this method is not very popular with intervening commanders because they are no longer "in control" of some of the information going up the chain of command.

The optimization and testing of deployment plans for their feasibility and of logistic plans for their support are roles for computers that have been emphasized in recent years with some success. There is now considerable experience with computers dealing with such one-sided problems. The prediction of outcomes of military actions—the role often envisioned for computers—seems to be most effective where physical parameters dominate, and perhaps where human conduct can be presumed to follow rigid doctrine. Computers have been used to support war gaming and campaign plan simulation and have provided some much needed insights. The two-sided nature of combat and the wide variability of human responses, however, make it difficult to predict outcomes of military action by any means.

There are a few fundamental facts about computers that need to be understood. In the first place, computers have some serious limitations. Their virtues of speed and consistency ought not to be inter-

preted as an ability to go beyond the accuracy and completeness of the information entered or the models programmed. The idea that computers add some sort of authenticity is to be resisted. Secondly, although application programs make computers useful, it is the computer's operating system that provides the basis for interoperability of systems and the transferability of programs. Finally, the problems of computer security are immense. There are risks that data could be disclosed, lost, or modified without authorization or knowledge, and that the same fate could overtake the programs on which commanders and their staffs rely. The measures to assure data security and integrity may be costly and cumbersome, and we may adopt the false hope that system security is assured. Yet, during World War II, nations wanted to believe that their communications encryption systems had remained secure, but found out after the war that they had not.

Trying to automate a process that one has been unwilling or unable to perform manually generally proves quite difficult. As people who automate an existing manual process discover, the initial automation reveals that further modifications of the process itself are possible, usually requiring a second upgrade. It might be assumed that if the possibilities for process modification had been recognized at the outset, both automation steps might have been done together. But taking the shortcut of combining both steps into one incurs the risk that when the completed system is delivered, it will fail to satisfy the user's expectations or desires; and when something goes wrong, it will be more difficult to understand why.

Commentary on the Case Studies and the Readings

Bouchard, the author of the first case study, believes (as do many others) that the Cuban Missile Crisis marked "a turning point in American civil-military relations and in the evolution of U.S. command and control doctrine," following which civilians would exercise both command *and* control. The term "control" is used by Bouchard to describe the limits placed on the discretion that has been otherwise delegated to subordinate decision makers. This case study on the Cuban Missile Crisis does not confine its focus to the deliberations of the executive committee (EXCOM), but examines in detail the methods used by the President to exercise a measure of control over naval operations, methods that may seem to some to

conflict with the traditional philosophy of command over commanders at sea.

Bouchard has read the available reports and has corresponded with many of the participants in order to pull together a reliable picture of the way that command was exercised over naval forces during that crisis. The book from which the case study was excerpted examines whether or not an inadvertent war could be triggered by military (in this case naval) interactions during a crisis. The author was specifically examining crises to see whether interactions between military forces at the scene of action became decoupled from the control of national authorities. In this crisis the author found no serious instances of decoupled interactions involving naval forces. For purposes of seminar discussion, students are asked to be prepared to identify any examples during the crisis where the command and control process appears to have broken down, or came close to doing so. *This is the prototype crisis situation: what command and control lessons should be drawn from it?*

Van Creveld describes some incidents on the Southern Front during the 1973 war between Israel and Egypt to illustrate how friction and the fog of war reduced the effectiveness of a previously successful, modernly equipped army that had a sound, well-developed command doctrine. This second case study is not strictly a crisis, but it focuses on the relationships (sometimes inverted) between civil officials and military commanders. After first providing a useful summary of the technical and doctrinal developments since the rise of Napoleon, van Creveld outlines the command doctrine developed by the Israeli Defense Force during the 1956 and 1967 wars. He also points out how the field radio had overcome the limitations of wirelines that had earlier restricted the movement of tactical commanders to fixed headquarters. Van Creveld describes how the Israelis seemed to employ what he calls "reverse optional control," which reduced the discretion of field commanders. *Which of the many reasons given by van Creveld for the Israeli failure are lessons that have larger application?*

Beal provides an interesting glimpse of the workings of the White House during crises. He characterizes decision making during crises as "organized anarchy." He laments the lack of analytic tools for decision makers at the highest level as well as the lack of tools for synthesis of information. He cites "Gray's Principle" to the effect that at every echelon, commanders must at some point act to accomplish

their immediate goals without further information.[1] Beal suggests that because of the anarchy that seems to pervade a crisis, decision makers should act very, very slowly, and should recognize as a key decision, the timing and the extent of the decision maker's (presidential) involvement. Finally, he emphasizes his belief that decision makers should be given options by lower echelons, noting that whatever options did survive to reach the decision maker they were likely to be detailed as to the facts, but lacking a guiding concept as the basis for action. *Should the President be informed immediately of any bad news or should he not be informed until lower echelons have rendered their judgments as to the local significance of the bad news and their advice as to what might be done in response?*

Beal decries in particular the failure to integrate information on its way to the President. *In your own experience, would it be valid to say that there is a failure to integrate information on its way to decision makers at all levels? Do these failures result from poor information integration, or from a lack of an integrated (presidential) perspective? What could be done to correct any such lack of integration?*

Following somewhat in Beal's footsteps, McDaniel describes what he felt Beal had accomplished, and what was left undone—particularly the tapping into giant databases. In this long excerpt, McDaniel goes on to lay out in some detail what the Congress may have had in mind when it created the National Security Council, and then describes how the NSC actually works, how it derives its power, and how its members functioned during the *Achille Lauro* crisis. He draws several interesting conclusions from his experiences: that our ability to predict crises is not likely to improve, that the utility of interagency committees results more from informal phone calls than from formal meetings, and that attempts to improve the process by involving other players will fail because of a pervasive drive to maintain security, whether for policy or bureaucratic reasons.

Demech provides a further description of Beal's attempts to introduce improved technology into the National Security Council, as well as the reluctance of the intelligence community to cooperate.

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[1] *General Alfred M. Gray, Jr. was Commandant of the Marine Corps from 1987 to 1991.*

Having read Beal, McDaniel, and now Demech, are you optimistic or pessimistic about the utility of "advanced" decision making facilities for national-level decision makers? Why or why not?

Grimes gives some examples of large corporations using the new technologies to help top management cope with crises. *In what ways are these examples relevant to the "crisis management" procedures and systems used in the executive branch of government?*

Readings

Case Studies

Bouchard, Joseph F. "The 1962 Cuban Missile Crisis," Chapter 4, *Command in Crisis*. New York: Columbia University Press, 1991.

van Creveld. Chapter 6, "Masters of Mobile Warfare."

Required Readings

Beal, Richard S. "Decision Making, Crisis Management, Information and Technology," in Coakley, pp. 23-50.

McDaniel, Rodney B., "C^3I: A National Security Council Perspective," in Coakley, pp. 68-101.

Demech, Fred R. Jr., "Making Intelligence Better," in Coakley, pp. 101-103.

Grimes, John, "Information Technology and Multinational Corporations," in Coakley, pp. 60-64.

Supplementary Readings on Command and Control During Crises

McCarthy, James P. "Commanding Joint and Coalition Operations," *Naval War College Review*, Winter 1993, pp. 9-21. [Deputy Commander-in-Chief, U.S. European Command describes the current use of joint task forces for operations in that theater. He emphasizes the roles played by the theater commander's headquarters acting as a bridge between policy considerations and local operational realities, by maintaining continuous

communications both with the staffs in Washington and the commander chosen to conduct the operation. With respect to the mission, he points out that success requires its thorough understanding as well as an expectation that it is likely to be modified during the operation. Finding that potential commanders of joint task forces may not be fully informed about the capabilities offered by forces other than their own, USCINCEUR has developed a Joint Warrior Program. He characterizes coalition operations as the toughest military endeavor.]

Woodward, Sandy. "The Bells of Hell," Chapter 8, *One Hundred Days: The Memoirs of the Falklands Battle Group Commander.* Annapolis, MD: Naval Institute Press, 1992. F3031.5 W66 1992. [The battle group commander describes how he precipitated the change in Rules of Engagement that authorized the sinking of *Belgrano.*]

Chairman, Joint Chiefs of Staff. "Crisis Action Planning," Chapter V, Volume I, *Joint Operation Planning and Execution System.* Joint Pub 5-03.1 Washington, DC: 1992. [Outlines the six phases of crisis action planning, defines the general responsibilities of the supported and supporting commanders during each phase, and describes the commander's estimates, planning orders, warning orders, alert orders, deployment orders, and execute orders used in crisis action ("time-sensitive") planning.

Niblack, Preston, ed. *Managing Military Operations in Crises: A Conference Report.* Santa Monica, CA: RAND, 1991. AS 36.R281, No. 4038. [Report of a January 1990 conference that had its beginnings as part of a project entitled Avoiding Nuclear War. This report summarizes much of what has been learned about the "management" of crises during the Cold War period, and attempts to show the relevance of those lessons for the post-Cold War world. Chapter 5 on the role of naval forces in crises is by Admiral Train.]

Allard, C. Kenneth. "Formative Influences on Modern Command and Control," Chapter 5, *Command, Control, and the Common Defense.* New Haven, CT: Yale University Press, 1990. [This chapter describes how the "lessons learned' from the crises of the

1960s and 1970s, the improved telecommunications and computer capabilities during the same period, and the amendments to the National Security Act all influenced the evolution of command and control and its supporting systems.]

Andriole, Stephen J. "Advanced Information Technology for Next Generation Decision Support" in *Advanced Technology for Command and Control Systems Engineering*. Fairfax, VA: AFCEA International Press, 1990, pp. 367-387. [A survey of developments in decision support systems (DSS) that we can anticipate in the near future. Andriole expects decision support systems to move from being data-oriented to becoming more able to provide analytical support. While he recognizes that decision support systems are more likely to be useful in structured situations where essential data is quantified, he also expects increasing use of systems where decision makers can manipulate graphic displays.]

Gorman, Paul F. "C^3I: USCINCSO's Perspective, 1983-1985." *Defense Analysis*, Vol. 4, No. 3, pp. 307-320, September 1988. [The Commander-in-Chief of U.S. Southern Command during the mid-1980s writes about his responsibilities, his operational command problems, and the actions he took to put his theater on a "war footing."]

Hyde, J.P., Warren, J.B., and Kesson, C.E. "C^3 Planning in Crisis Response," *Principles of Command and Control*, pp. 249-255 (1986); reprinted in *Naval Command and Control*, edited by Vinny DiGirolamo. Fairfax, VA: AFCEA, 1991. [A survey of actions taken to improve the abilities of communications planners to respond to the demands of crises; describing what it is like to plan for communications during a crisis; and identifying some of the communications assets available to assist both the planning and the execution of operations during a crisis.]

Neustadt, Richard E. and May, Ernest R. *Thinking In Time: The Uses of History for Decision Makers*. Free Press, New York: 1986. [This important book describes the U.S. policy-making process during a number of post-World War II crises: particularly the Cuban Missile Crisis, pp. 1-16, the outbreak of the Korean War,

pp. 34-48, and the Mayaguez Incident, pp. 58-66. The authors describe both the uses and misuses of history, and the importance of asking some fundamental but simple questions at the outset: what is *known*, *unclear*, and *presumed*? what are the *likenesses* and *differences* between the present situation and those of the past? and what can we do *now*?]

Branch, Stuart E., "C^3I and Crisis Management," in Coakley, pp. 53-54 (1984). [Discusses the problem of too much information.]

Goodman, H. and Schiff, Z. "The Attack on the LIBERTY," *The Atlantic Monthly*, September 1984. pp. 78-84. [This article describes the Israeli attack on *USS Liberty* in June 1967. It is based on war logs of the Israeli Navy and two investigations of the incident by the Israeli Defense Forces. The description illustrates how a number of factors—fear, frustration, uncertain identification, miscalculations of ships' speeds, and the assumption that an exploding ammunition depot was the result of shelling—all combined to lead Israeli operational commanders to misjudge the situation and make faulty information decisions.]

Hayward, Thomas B. "An Ex-CNO's Reflection on the Garbage Can Theory of Naval Decision Making." *Ambiguity and Command*, pp. 258-268. [Admiral Hayward distinguishes the decisions with which he was involved as being strategic (a superpower war), tactical (aircraft shootdowns or hostage rescues), or bureaucratic (peacetime budget issues). He concludes that the "garbage can" theory appears to have relevance to the examples from his own experience.]

Rowden, William H. "Sixth Fleet Operations: June 1981 to July 1983." *Ambiguity and Command*, pp. 269-276. [Admiral Rowden describes what he did during some crises that arose while he was Commander, U.S. Sixth Fleet: the shootdown of Libyan fighters over the Gulf of Sidra, the assassination of Anwar Sadat, and the bombing of the U.S. embassy in Beirut. He then reflects on his decision making during these crises.]

Train, Harry D. "Decision Making and Managing Ambiguity in Politico-Military Crisis." *Ambiguity and Command*, pp. 298-307.

[Admiral Train describes several crises, including a collision between a U.S. frigate and a Soviet submarine, the sending of helicopters used for the Iranian Hostage Rescue, and acting as a relay for questions from the President to a unified commander. He then suggests what we might learn about making decisions in the presence of ambiguity.]

Howe, Jonathan T. *Multicrisis: Sea Power and Global Politics in the Missile Age*. Cambridge, MA: MIT Press, 1971. V25 H68. [Analyzes the Quemoy Crisis of 1958 and the Arab-Israeli War of 1967 with the objective of understanding how they affected the superpower relationship between the US and USSR. The Quemoy crisis is one of the four crises later studied by Bouchard in *Command in Crisis*].

Allison, Graham T. *Essence of Decision: Explaining the Cuban Missile Crisis*. Boston, MA: Little, Brown, 1971. [A classic study of the decisions made during the Cuban Missile Crisis using three quite different models of human behavior: the rational actor, the organizational process, and bureaucratic politics.]

Loomis, Richard T. "The White House Telephone and Crisis Management." U.S. Naval Institute *Proceedings*, December 1969, pp. 63-73. [The evolution of the use of the telephone and other electronic media by the President as Commander-in-Chief, from the first "war room" of McKinley to the high tech conclusion of the Johnson administration (when the article was written); also describes some of the crises of the 1960s and how presidents have learned to exploit the capabilities of the new technologies available to them.]

Supplementary Readings on Computers

Sproull, Lee and Kiesler, Sara. "Computers, Networks and Work," *Scientific American*, September, 1991, pp. 116-123. [Computer workstations were initially installed in command centers to facilitate the work of staffs; since then workstations have increasingly been used on computer networks for computer conferences, either to deal with rapid information exchange during crises or to iron out the myriad details of deliberate plans.

Sproull and Kiesler discuss the group dynamics of electronic mail, that in effect establishes such computer conferences. They describe the unexpected impact of such conferences on individual participants and on their collective behavior, posing some interesting managerial problems for the future.]

Tesler, Lawrence G. "Networked Computing in the 1990s," *Scientific American*, September 1991, pp. 86-93. [Traces the evolution of the role of computers from oracle to work station to active assistant, an evolution made possible by the continuing decline in the cost of computing (halving every three years) and the increasing sophistication of computer users. Tesler describes the current trend toward the employment of networks of computers. He concludes that universal connectivity could even enhance democracy, but such a result is by no means certain.]

Taylor, Edward C. "AI in Command and Control: What and When," *Proceedings of the 1987 Command and Control Research Symposium*. McLean, VA: Science Applications International Corporation, 1987, pp. 379-384. [A survey of three alternative approaches to the application of artificial intelligence to command and control problems:

- Developing expert systems to apply the logic and rules used by human experts,
- Developing machines that apply parallel processing techniques apparently used by the human brain, or
- Developing systems that exploit human-machine symbiosis.]

Winograd, Terry and Flores, Fernando. *Understanding Computers and Cognition: A New Foundation for Design*. Norwood, NJ. Ablex Corporation, 1986. [A book about the philosophies that underlie the use of computer technology. Dedicated to the people of Chile (one of the authors held high posts in state-owned corporations and in government there) the book evolved into a discussion of some of the objectives that might be achieved through the design of future computers. The authors argue that computers have a particularly powerful impact on individuals and society because in using them we engage in a discourse organized

in a way that reflects a rationalistic tradition that may be at odds with human experience.]

Ware, Hugh. "New Tools for Crisis Management," U.S. Naval Institute *Proceedings*, August 1984, pp. 19-24. [The crises of the 1960s were not always dealt with efficiently and effectively, which focused considerable attention on the shortcomings of C^3 systems. Ware (writing in 1974) describes a number of these crises: the capture of *Pueblo*, the attack on *Liberty*, and the Cuban Missile Crisis. In addition to recommending improvements in communications systems, Ware offered some suggestions for crisis management—positive acknowledgements of messages, *ad hoc* C^3 structures, and *ad hoc* staffs and planning.]

PART THREE:

Command, Control, Communications, and Computer Systems

SESSION 7
C^4 *Systems for Conventional Forces / Interoperability*

The ideal command and control system supporting a commander is such that the commander knows what goes on, that he receives what is intended for him and that what he transmits is delivered to the intended addressee, so that the command decisions are made with confidence and are based on information that is complete, true and up-to-date.

Defense Science Board Task Force on Command and Control Systems Management (1987)

A good C^3I tactical system has to be able to degrade gracefully; that is, it must be able to lose some of the capability that it started with initially, and still not come unglued.... As we concentrate...on how best to design the C^3I system, there's a tendency to envision one that's centralized—but frequently centralized systems don't degrade gracefully.

Thomas H. McMullen (1982), quoted in *C^3I: Issues of Command and Control*

The greatest leverage in system architecting is at the interfaces.... The greatest dangers are also at the interfaces.

Eberhardt Rechtin in *Systems Architecting*

Focus

The four remaining sessions of the course will focus on C[4] systems. In this session we examine the C[4] systems used by forces engaged in conventional war and review current efforts to achieve interoperability. The session will also include discussion of the students' descriptions of C[4] systems for conventional forces.

C[4] Systems for Conventional Forces

This is the first session focused on C[4] *systems* rather than on the command and control process. We will examine some of the characteristics of "ideal" systems listed by the Defense Science Board in the first epigraph, as well as others that are not. We should look critically, however, at their idea that command decisions can ever be made "with confidence," or that information can ever be "complete, true and up-to-date." We will explore both the capabilities of systems that support command and control and some of their limitations. We will question whether commanders can ever be (as the Defense Science Board seems to suggest) separate from the C[4] systems that support them, and will consider the extent to which leadership skills and decision-making styles are integral parts of C[4] systems.

One of the major influences on the design of C[4] systems is (or should be) the underlying philosophy of the command and control process. It is possible, for example, to imagine a rigid command and control process that prescribes specific actions for each anticipated set of circumstances, and which prohibits actions without reference to higher authority when an unanticipated circumstance arises. On the other hand, it is possible to visualize a much more flexible command and control process that authorizes any action that in the commander's judgment contributes to the achievement of the unit's mission, and that permits informing higher authority of such actions only "after the fact." It is also possible to visualize a command and control process in which all echelons are provided essentially the same facts for analysis, on the premise that reasonable commanders at each echelon, given the same facts and a common objective, would most likely take the same action. The C[4] systems that support different command and control processes—different command philosophies—are likely to be optimized differently.

Furthermore, the complexity of C^4 systems increases in proportion to the number of possible situations to be dealt with and to the number of possible responses. C^4 systems tend to be reasonably simple when the number of possible situations are few and when the repertoire of possible responses to each situation is small. Thus a C^4 system for strategic nuclear warfare, despite its size, is inherently simpler than a tactical C^4 system that must cope with larger numbers of alternative situations and consider a broader range of alternative courses of action. It is of course true that to some extent the complexity of C^4 systems is also related to the number and variety of the forces involved, but a greater component of complexity has to do primarily with the number of potential situations and responses.

The systems to be examined here are the command, control, communications, and computer (C^4) systems that support the process that commanders employ when "planning, directing, coordinating, and controlling" forces under their command. This relationship between process and systems merits some consideration. Any procedure that helps commanders reduce the uncertainties at the time for decision and action can be viewed as part of their command and control process. The frequent discussions that Lord Nelson held with his unit commanders and commanding officers, for example, were clearly a part of his command and control process.

Yet while each commander may shape a unique command and control process, the C^4 system that supports one commander often supports other commanders as well. A command, control, communications, and computer system includes (in addition to command facilities and intervening communications links) such elements as doctrine, training, and rules of engagement. The mix of "static" components—like doctrine—and "dynamic" components —direct communications and interactive access to computers—will vary from system to system.

C^4 systems for conventional forces reach from the unified or specified combatant commander down through all echelons in the combat units. C^4 systems from the theater commander through component commanders or joint task force commanders to senior tactical commanders are usually referred to as theater systems, whose emphasis is on providing reliable connectivity often over considerable distances. C^4 systems that are wholly within tactical formations are

usually referred to as tactical C^4 systems, optimized to create viable and effective combat units and characterized by mobility, reliability, and simplicity. Interoperability problems within tactical formations are minimized by the use of standard radio frequency plans and common radio wave forms, procedures, crypto systems, and keying materials. While the use of identical equipments at each end is often seen as the solution to interoperability problems, it is the use of common wave forms rather than the same equipment that achieves interoperability, along with common doctrine and procedures.

This course might have included intelligence systems as an integral part of C^4 systems but did not, and this arbitrary choice should not go undiscussed. Whether C^4 systems ought to include or exclude intelligence systems is not an easy question to resolve. C^4 systems and intelligence systems intersect at many points: they use the same technologies, and the purpose of the intelligence process is clearly to support the exercise of the command function. In practice, however, commanders today are served by two separate sets of systems: those for command and control and those for intelligence. C^4 systems and intelligence systems are currently designed and managed as separate systems, sometimes for reasons of security, sometimes for historical or bureaucratic reasons. Yet as true cooperation between operations officers and intelligence officers continues to spread, it is possible to foresee a gradual integration of C^4 systems and intelligence systems into true C^4I systems and to speculate that such an integration is likely to be accomplished first at higher levels, and move down. *What would be the benefits and the drawbacks of such an integration of C^4 and intelligence systems into true C^4I systems?*

Even though the principles of the command and control process may remain relatively unchanged, technology is changing the way supporting systems actually function. Quite apart from advances being made in the coverage and accuracy of sensor systems that generate the information used by C^4 systems, technological advances in telecommunications and computers are modifying the ways that C^4 systems provide the following capabilities:

- Communicating reliably and securely over great distances,
- Enabling commanders to absorb information efficiently and to assess the existing situation, and

- Assisting commanders to predict the probable outcomes of alternative courses of action.

These technological changes result largely from the application of digital computers and advanced transmission systems. Despite the greater use of digital systems to facilitate both the manipulation and transmission of information, the originators and recipients—the commanders themselves—speak and perceive in analog form. The use of digital computers makes it necessary (at least at the moment) to convert data and information from analog to digital form at input, and from digital to analog form at output. Some of the problems encountered in command and control are related to these conversions. Who bears the burden for them? On the input side, until computer programs are available that enable computers to accept human voice input directly, commanders or their staffs need to make the conversion by typing, formatting, or otherwise disciplining verbal and written information so the computer can deal with it. For some positional and other numeric data, it has been possible to design work stations so that a skilled operator can make digital inputs by positioning ball tabs or similar analog devices.

On the output side, the danger in relying too heavily on displays, particularly digital displays, is that they may not reflect the degree of uncertainty that surrounds the position, composition, identity, or even the existence of the targets displayed. The digital world is a world based on the definite presence or absence of data, and so a digital display expresses a degree of certainty that may be unjustified. This inability to portray the uncertainties of data is separate from the inability of a database to reflect changes in a situation that have occurred since the last reports were received, changes likely to be significant in a fast-breaking situation.

Interoperability

Success of a joint operation may well depend on whether units from different Services operate at a level of cooperation beyond "compatibility" (defined as "functioning without mutual interference") and achieve "interoperability," defined (in Joint Pub 0-1) as:

> The ability of systems, units or forces to provide services to and accept services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together.

Such services would certainly include close air support, fire support, and early warning, for example. With respect to communications-electronics systems, "interoperability" is further defined as:

> The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users.

A recent Department of Defense Directive (cited in the Supplementary Readings), has announced the policy that C^3I systems for joint and combined operations by U.S. forces must be compatible, interoperable, and integrated, and that *all* C^3I systems developed for use by U.S. forces are considered to be for joint use.

Although the harmonization of systems is a major part of the overall interoperability effort, it is by no means the only part. In 1989, for example, the "interoperability agenda" of the joint staff consisted of fifty-eight items, fewer than half of them considered "materiel." The other categories (in descending size) were "doctrine and procedures," "operations planning," and "training and education." For command and control purposes, there are three broad components of interoperability: doctrine and procedures, messages, and hardware. Agreed common procedures are found in widely distributed doctrinal publications and in "standing operating procedures," both of which form the basis for normal training. The special operating procedures activated for a specific operation are usually spelled out in an annex to the operation order. Intense communications planning has been necessary to achieve the standardization of circuit procedures, the sharing of common crypto keying material, and the efficient allocation of radio frequencies and satellite channels.

With respect to messages, there are three areas of concern: vocabulary, message formats, and circuit procedures. For joint operations, standardization of vocabulary and message formats and of circuit procedures for automated tactical data links is being accomplished through a program to develop a series of message text formats for word-oriented message reports, and a family of tactical

digital information links (TADIL) messages for bit-oriented messages between automated tactical data systems. This program also provides the U.S. positions during efforts to agree on similar standards for combined operations.

With respect to hardware, a major issue is whether or not radio equipment at each end is capable of transmitting or receiving electrical signals with a common wave form, a capability that *can* be achieved using different hardware so long as signal interface standards have been established and observed.

The Grenada Operation in 1983 provided a practical test of the extent to which interoperability was then achievable by joint forces operating together on short notice and for the first time. Significant problems of interoperability during the operation were reported in the press. No unclassified official reports are available that detail the problems that actually occurred or describe the specific actions taken to prevent those specific problems from occurring in the future. An instruction on interoperability was subsequently issued by the Secretary of Defense, as well as a memorandum of policy on the same subject by the Joint Chiefs of Staff. A new division devoted to interoperability was created in the Joint Staff, and the general "backwash" from the operation may have contributed to the congressional concerns that led to the DOD Reorganization Act of 1986.

Because interoperability is obviously a desirable objective, it is surprising to encounter occasionally some genuine resistance to its achievement. Among the causes for such resistance are an organization's pride in doing its mission well. These "organizational ways" have often been reflected in specifications and unique hardware. Whenever an organization has to abandon its way of doing things and adopt new standards, there may be a sense that such an abandonment is equivalent to admitting that previous standards were somehow flawed (when in fact they might have been superior to the new standards adopted to achieve interoperability). Resolving the problems of interoperability requires a focus on the larger objective of joint or combined operations.

A more serious problem arises when an organization finds itself paying a high price to achieve interoperability with other organizations: when it has to change its procedures, vocabulary, or

standards, or has to abandon or modify a line of equipment. The solution may be to recognize at the outset that the achievement of interoperability is going to cost money, either to make the necessary changes or to expand the capabilities of equipment to cover the operating requirements of additional potential users. In order to eliminate the fear that the "losers" will bear all these costs, it seems prudent either to fund "interoperability" projects centrally or to agree in advance that these costs ought to be distributed in some equitable way among *all* the organizations whose operations stand to benefit by the achievement of interoperability. If this were done, the "funding" issue would recede as a consideration, and contending organizations could focus primarily on achieving interoperability objectives.

The achievement of interoperability for combined operations, in which the forces of friendly nations are organized to operate and fight together, is even more difficult. The command and control of a combined operation requires resolution of all the issues that arise in a joint operation, but in addition, requires coping with national policies on communications security and on the protection of intelligence and sources, as well as with considerations of national pride. The interoperability problems that can arise during combined operations with Third World nations may be very great indeed. The interoperability problems already encountered by the many agencies involved in mounting the "war on drugs" can provide some insights into problems of "combined interoperability."

We can expect that interoperability will be a continuing problem. Even though both joint operations and coalition operations have recently focused attention on the need for interoperability in C^4 systems, we should not ignore the long history of breakdowns and misunderstandings that occur even in operations wholly within one Service. Solutions have come only with common doctrine, common procedures, and common exercises. *What actions would you recommend be taken now to improve the interoperability of C^4 systems for joint and combined operations during the crises or wars of the future?*

Commentary on the Case Study and the Readings

Van Creveld surveys command and control during the Vietnam War from 1965 to 1968. He cites the complexity of weapons systems and the resulting specialization of personnel as the causes for a twentyfold

increase between 1945 and 1985 in the amount of information needed to control individual units, an increase he feels has led to inevitable centralization and a greater dependence on reliable and rapid communications. He concludes that while up-to-date technical means of communications and data processing are absolutely vital to the conduct of modern war, they are not in themselves sufficient to make command systems effective. *What in your experience makes a C^4 system effective? Do you believe that an increasing reliance on telecommunications leads to an inevitable drift toward centralization?*

Van Creveld also describes the use of helicopters as directed telescopes and asserts that they distort the operation of the subordinates' command systems. *Is a directed-telescope system possible today that does not cause such distortion? Has it ever been possible to avoid such distortion?*

In a footnote, van Creveld defines "information pathology" as the inability of organizations ("owing to structural defects") to obtain a clear, timely picture of their surroundings and their own functioning. *What is the cause of information pathology? What is its cure?*

Rechtin provides a broad survey of the technologies that have been applied to command and control since the start of World War II, and he explores some of the vulnerabilities that reliance on these technologies has created. He identifies some of the issues about which the perspectives of commanders and of technologists differ, and concludes that the control of information is a command function. Rechtin questions whether a commander should be made to adapt to supporting C^4 systems, and feels that the system should be made to adapt to the commander. *Which course would you recommend? Why?*

General Powell has written a one-page article apparently designed to challenge the computer industry. Here he summarizes the importance of personal computers and automated message networks to the Persian Gulf War. He is trying to convey the "commander's perspective" to computer engineers. *Is his goal—to give battlefield commanders access to all the information needed to win the war—realistic or achievable?*

Beaumont looks at the impact that command and control technologies have had on the way that military commanders and their staffs function, and then cites some of the reasons that combat officers have given for resisting these technologies. He notes the

effect of fatigue and stress on problem-solving abilities, and speculates about the extent that people in the command and control loop are assets, and about the extent to which people in the loop become liabilities. He suggests that methods be developed to detect deterioration in a commander's performance. *Can you foresee a time when this will be both possible and wise?*

General Livsey describes what he did in Korea to build a C^4 system to support his command and control needs, and outlines the problems he encountered. The importance of this article is that it provides a glimpse into the thought process of a responsible commander as he works his way through decisions about what he really needs in the way of a C^4 system, and considers what could go wrong with it. *Should this sort of personal involvement by the commander in the details of the C^4 systems be encouraged? If so, how?*

General McKnight, formerly Director for C^3 Systems, Joint Staff, describes the steps being taken to improve interoperability among U.S. military forces. He identifies the following as contributing to the interoperability effort: management structures, common equipment, common standards, common doctrine and tactics, and common techniques and procedures. *Are you persuaded that all of these efforts are necessary in order to achieve interoperability?*

The pamphlet on "C^4I for the Warrior" purports to set forth a concept that is affordable, responsive, and would allow warriors to perform any mission, any time, any place. *What is the concept? How does it differ from previous concepts?*

This session is the first of three in which the current version of Joint Pub 6-0 will be read and discussed. Note that the subject of this publication is not the command and control process but C^4 systems to support joint operations. For this session, the chapters on doctrine, principles, and employment are assigned. It will be obvious that writing doctrine for C^4 systems is not an easy task. *Do you find the "doctrine" as outlined in Pub 6-0 (and adapted from previous doctrine for communications-electronics equipment) to be relevant and useful? Are the "principles" of C^4 systems as outlined in Chapter II really principles or just characteristics? What principles do you feel ought to govern the design and operation of C^4 systems so that they will enhance the command and control process?*

Readings

Case Study

van Creveld. Chapter 7, "The Helicopter and the Computer."

Required Reading

Rechtin, Eberhardt. "The Technology of Command," *Naval War College Review*, March-April 1984.

Powell, Colin L. "Information-Age Warriors," *Byte*, July 1992, p. 370.

Beaumont. Chapter 2, "People in the Loop: Human Dimensions in Command and Control."

Livsey, William J. "Tin Cans and Strings: The Concept, Design and Construction of an Evolutionary C^2 System," *Principles of Command and Control*, pp. 75-83 (1987).

McKnight, C.E., Jr. "Solving the Interoperability Problem," *Principles of Command and Control*, pp. 382-388 (1985).

"C^4I for the Warrior." C^4 Architecture & Integration Division, The Joint Staff, Washington, DC. 1992.

Joint Pub 6-0. "Introduction," "C^4 Systems Principles," and " C^4 Systems Doctrine for Employment, Configuration, Plans and Resources," Chapters I, II, and III.

Supplementary Readings on C^4 Systems for Conventional Forces

Cebrowski, A. K. and Loescher, Michael. "The New Warfare: SEW," U.S. Naval Institute *Proceedings*, February 1993, pp. 92-95. [An articulation of Navy thinking about a warfare mission area called "Space and Electronic Warfare (SEW)." The article defines SEW in the context of such other Navy warfare areas as amphibious

warfare, strike warfare, anti-air warfare, and anti-submarine warfare. From the perspective of SEW, command and control is only one of eight "disciplines," and it is not one of the four warfare disciplines but one of four *supporting* disciplines, along with operational security, surveillance, and signals management. In this view, the Command and Control, Communications and Computer, and Intelligence (C^4I) System is only a subsystem of space and electronic warfare.]

Secretary of Defense. "Command, Control, Communications (C^3), and Space," Appendix K of *Conduct of the Persian Gulf War: Final Report to Congress*. Washington, DC, April 1992. [The second half of this report (pages K-25 through K-51) provides a description of the equipment used and the measures taken to provide C^3 systems for the Gulf War.]

Secretary of Defense. "Command, Control, Communications and Intelligence," *Annual Report to the Congress*. [Each year, the SECDEF describes the wide range of programs needed to provide secure, interoperable, and enduring C^3 systems.]

Allard, C. Kenneth. "Tactical Command and Control of American Armed Forces: Problems of Modernization," Chapter 6, *Command, Control, and the Common Defense*. New Haven, CT: Yale University Press, 1990. [In this chapter, Allard describes how each of the Services tended to resolve the conflicting pressures as they set out to modernize their command and control structures and (what were then called) their C^3 systems. The interplay between the integrative potential of C^3 systems and each Service's command structure was somewhat different, reflecting the differences among the Service environments.]

Otis, Glenn K. and Driscoll, Robert F. "Making the C^3 Pieces Fit in Central Europe," *Principles of Command and Control*, pp. 297-301 (1987). [A description of some programs intended to modernize C^3 systems for a major war in Europe.]

Hopple, Gerald W. "Air Force Command and Control: Assessment Criteria for Computer Based Decision Aiding Systems," *Principles of Command and Control*, pp. 95-116 (1987).

[Describes the generic command and control process in the Air Force and lists the characteristics of command and control that ought to be considered in the development of decision aids for that Service.]

Latham, Donald C. "21st Century Battle Management: Penetrating the 'Fog of War,'" *Principles of Command and Control*, pp. 407-412 (1987). [Latham (writing during the Cold War) visualizes the command and control capabilities that he expected to be at the disposal of commanders (in Central Europe) in the year 2000, based on programs already under way. The systems to provide these capabilities were to be operated by a generation of Americans fully familiar with computers and information management systems. He concluded that one of the keys to a commander's success on battlefields of the twenty-first century would be an ability to use C^3 systems to penetrate the "fog of war."]

Ward, R. E. and Brennan, William J. "Navy Battle Force Command and Control—A Tactical Coordination and Tactical Communications Management Perspective," *Principles of Command and Control*, pp. 165-178 (1985). [An approach taken by the Navy to create a command and control capability to support a battle group commander to defend against high-speed missile attack. This article draws a useful distinction between two time domains: a first time domain with a time line of less than ten minutes, within which targeting and other aspects of an engagement take place, and a second time domain, longer than ten minutes, in which surveillance and planning take place.]

Bohannan, Anthony G. "C^3I in Support of the Land Commander," *Principles of Command and Control*, pp. 179-193 (1984). [Describes command and control requirements of ground commanders emphasizing the leadership aspects of the commander's role. In contrast to Latham, Bohannan would reverse the trend toward more capable and more complex data systems for the land commander and would place more emphasis on secure voice and mobility.]

Ruhe, William J. "Soviet Submarine C^3," *Principles of Command and Control*, pp. 289-296 (1984). [The Soviet approach to command and control of their attack and ballistic missile submarines, showing how the Soviets took seriously the lessons learned from the experience of Doenitz and his wolf packs in World War II.]

Supplementary Readings on Interoperability

Chairman, Joint Chiefs of Staff Memorandum of Policy XXX, "Compatibility, Interoperability, and Integration of Command, Control, Communications, Computers, and Intelligence Systems," April 1993. [This memorandum elaborates on the DOD Directive on the same subject (summarized below). It prescribes the joint review of requirements, the application of standards, the certification and testing of new equipment, and configuration management. It also includes information on "C^4I for the Warrior."]

Department of Defense Directive 4630.5, "Compatibility, Interoperability, and Integration of Command, Control, Communications, and Intelligence (C^3I) Systems," November 12, 1992. [This is a revision of a directive issued initially in 1985. It is important to note that in this new version, the word "Integration" has been added to the title, and the word "Tactical" deleted as a modifier of C^3I systems. These changes reflect SECDEF's intention to move beyond basic interoperability, as well as to erase the "tactical/strategic" systems lines that had been drawn in the past. The new DOD policy is that C^3I systems for joint and combined operations by U.S. forces must be compatible, interoperable, and integrated, and that *all* C^3I systems developed for use by U.S. forces are considered to be for joint use.]

Department of Defense Instruction 4630.8, "Procedures for Compatibility, Interoperability, and Integration of Command, Control, Communications, and Intelligence (C^3I) Systems," November 18, 1992. [Issued in support of the DOD directive above. Tasks the commanders of unified and specified combatant commands to assess new or modified C^3I systems for their impact on joint task force operations and to report any incompatibility or lack of effective interoperability and integration. It tasks the

Director, Defense Information Systems Agency to be the DOD single point of contact for development of technology standards for information processing and information transfer and to conduct a program to verify whether emerging C^3I systems are indeed interoperable.]

SESSION 8
C^4 *Systems for Strategic Forces / Survivability*

You have to begin thinking about what kinds of things you are going to need to deter in a new environment. And one of the first things needed, I think, is ability to ensure, under the most adverse conditions, that we can stay in control.

William Odom (1980), quoted in
C^3I: Issues of Command and Control

Physical survivability is important, and most survivability conversation, thinking, and studies deal with physical survivability. But perhaps an even more serious problem today, given all the electronic systems we use, is electronic survivability—being able to resist an electronic attack.

Lee Paschall (1980), quoted in
C^3I: Issues of Command and Control

Focus

We now examine the special problems of the C^4 systems created for the command and control of strategic forces and discuss student papers that describe strategic C^4 systems. Although most of the strategic C^4 systems have been developed for command and control of nuclear forces, the term "strategic" is used here to identify those systems designed to support direct command and control by national command authorities and could apply as well to other weapons of mass destruction.

C^4 Systems for Strategic Forces

No one has fought a nuclear war, so the problems and difficulties of doing so have had to be imagined. What had become clearer by the late 1980s, however, is that the ability to command and control nuclear forces at the same time that the nation is itself the target of a nuclear attack is a problem of great difficulty and complexity. It is a problem equaling if not surpassing in importance the problems that had been the focus of nuclear planners during previous decades: the coverage and potential false alarms of early warning systems, the reliability of weapons systems, and the effectiveness of delivery systems.

In the next session (on C^4 system architecture), we will examine how the command and control process is reflected in the architecture of supporting C^4 systems. During this session, observe how elaborate a C^4 system can become even though it serves only a single decision maker responding to a small number of predictable situations, and constrained to a single decision involving a choice from a limited set of alternative actions. Conventional C^4 systems, in contrast, need to support decisions being made at four or five echelons, about an almost unlimited set of situations, each decision maker able to direct actions of forces with extensive capabilities and flexibility.

C^4 systems for strategic forces illustrate very clearly the three parts of the command and control process. The first part—which leads up to the situation assessment—consists of moving information from a variety of sensors through the correlation, filtering, and analysis process to the commander: in the case of nuclear war, to the President.

Once the President makes an information decision about what is actually happening, the focus can shift to the second part of the command and control process: the making of the operational decision about what action to take. Only a short time was expected to be available between the information decision and the strategic operational decision (at least for the execution of some of the options available). Therefore, appropriate courses of action were developed for each foreseeable situation, and each course of action was planned in complete detail. The alternative courses of action available for operational decision are like football plays: planned in advance and with great detail. Operational decisions can thus be viewed as having been made over a long period of time, awaiting only the making of

an information decision (in real time) to trigger the final decision as to which option to execute (like calling a football play that has long been planned and practiced for execution when the situation is judged to be appropriate).

The third part of the command and control process—getting operational decisions communicated for execution, and then monitoring that execution—is expected to be taking place even as the C^4 system that supports execution is under attack, so a need exists for alternative links and nodes to assure system survival after an attack on the system has begun.

In concept, at least, strategic C^4 systems—because they have been designed to respond to a relatively small number of situations with a small number of alternative actions—are simpler than tactical C^4 systems that need to respond to a larger repertoire of situations with a larger number of alternative responses. Such relative simplicity does not, however, diminish either the difficulty or importance of solving tough technological problems in strategic systems, problems that have had to be solved without the "benefit" of actually having experienced nuclear war, with its anticipated degradation in performance of both systems and people.

The objective of strategic command and control has until recently been to respond effectively (and massively) to an actual all-out nuclear attack against the United States. It is now likely that strategic C^4 systems will in the future have to provide as well for the delivery of a small number of U.S. nuclear weapons (or other weapons of mass destruction) against a wide variety of targets and under a wide variety of circumstances. Strategic C^4 systems will have to continue to be capable of effectively preventing unauthorized use of U.S. weapons, while assuring that when a proper order has been issued, the delivery of weapons will be prompt and effective. In a broader context, however, strategic C^4 systems will now be part of a national strategy to deter use of nuclear weapons (or other weapons of mass destruction) by the increasing number of nations that possess them.

The elements of the U.S. strategic C^4 system described in the readings were developed to support a nuclear command and control concept of responding to one massive nuclear attack by the launching of another. Strategic C^4 systems of the future are likely to be planned around the possible use of nuclear weapons on a much more selective basis: on a small number of targets chosen only as events unfold. U.S. strategic systems will have to be capable of locating and

targeting weapons of mass destruction and of responding quickly and reliably to their use. The stress on C^4 systems may be intense in order to fulfill the expectations of nations that believe the U.S. has the capability to respond effectively.

Survivability

To avoid or minimize damage to a C^4 system, its components (its nodes and links) must be made either more difficult to find or more difficult to degrade. There are three approaches to improving such a system's survivability:

- Making mobile some of the key nodes in the system,
- "Hardening" individual nodes and links to increase their ability to resist physical and electronic attack, and
- Proliferating a system's links and nodes to provide alternatives and backups so that no single attack can destroy completely the essential *system.*

For strategic command and control, the ultimate objective is maintaining an effectively functioning system even under attack. Yet in the case where the strategy is deterrence of attack, a more achievable objective is to maintain a high enough probability of continued functioning during and after an attack that an attacker could not be absolutely sure of rendering the system as a whole inoperative by attacking it.

Like other elements of a military force, C^4 systems are subject to physical attack: that is, the destruction of command centers, communications centers, and transmitter and receiver sites. But unlike other elements (with the notable exception of sensor systems), telecommunications systems are also subject to electronic attack in the form of destructive electromagnetic pulses, electronic manipulation, or electronic jamming. Although all of these forms of attack are possible, particular effort has been devoted to resisting electronic jamming. In terms of Shannon's theory of communications (outlined in Session 5), defense against jamming requires a receiving station to distinguish the transmitter's signal from the jamming signal ("noise" in Shannon's model). Jamming resistance is achieved either by processing the transmitted signal in a way that minimizes the jamming signal in comparison, or by using directive antennas at the

receiver that captures the transmitter signal but nulls out the jamming signal. In satellite communications systems, there are two opportunities for a jammer: on the uplink and on the downlink, but the uplink is considered more vulnerable because it can be jammed from a much larger area.

Commentary on the Readings

Carter's *Scientific American* article describes the nodes and links in C^4I systems for waging nuclear war. He describes the components of a C^4I system—command posts, the sensors, and the links in the command network—and identifies their vulnerabilities. He concludes that although advanced technologies can and should be exploited to improve strategic C^4I systems, the fundamental unpredictability of nuclear war makes it difficult to foresee the physical behavior of C^4 systems and to predict the interactions of people and machines in chaotic circumstances. *Do you agree with Carter that in many ways the most vital challenge to C^4I systems is not the support they provide during a war but the effective management of crises that could be the prelude to war?*

In his article from *Managing Nuclear Operations*, Carter identifies as a chief concern the likelihood that system vulnerabilities if exploited by an enemy could result in reduced capabilities that in turn would lead to loss of control. He points out that analyzing the vulnerability of one's own C^4 system really requires stepping through the targeting problem faced by one's opponent. The hypothetical targeter attempts to view the opposing C^4 system as a *system* and then to identify those targets that would most quickly, most severely, and most permanently interfere with that system's functioning. Carter leads us through such an analysis from which he identifies some eight factors that he expects would be considered by strike planners and command authorities. He identifies three target sets—command centers, command links, and sensors—and assesses how C^4 vulnerabilities would most likely affect the U.S. ability to launch retaliatory strikes following a major Soviet attack. He goes on to identify Soviet targets whose early destruction would reduce the vulnerabilities of U.S. C^4 systems. *Is Carter's logic for assessing vulnerabilities to a nuclear attack the same as or different from the logic that would be useful for assessing vulnerabilities to conventional or unconventional attack?*

General Dougherty uses the phrase "psychological climate of nuclear command" to refer to the strict military discipline that a nuclear commander expects of his people (and that is expected of him as well). The article gives us a glimpse of the mind-set of this retired Commander-in-Chief of the Strategic Air Command (CINCSAC), whose focus was ever on "execution." He discusses some of the issues faced by an officer in that high position: nuclear targeting, the laws of armed conflict, training and human reliability, and the importance of unequivocal execution orders. He concludes that "nuclear launch situations will require a visible military logic that is in keeping with the combat crews' instilled military discipline and that will justify the necessity of their actions," and that "the procedures must eliminate reasonable personal doubt about the legitimacy of the order or the need for action." *What requirements do these objectives place on the command and control process?*

In contrast, Keegan, in the final chapter of his book about the heroic image of commanders, concludes that the martial qualities of the successful commanders of the past are not relevant to the needs of any nuclear war of the future, which he calls "post-heroic leadership." He finds that commanders seek to turn from the complexities of strategy to the simplicities of tactics, where the velocity of decision making is more to their liking. *Do you agree with Keegan that, for nuclear war at least, the heroic ethic is dead?*

In a similar vein, Beaumont, after describing some of the foreseeable problems of command and control systems designed to support the fighting of a nuclear war, expresses more concern about problems on the human side of the man-machine interface. He questions whether the lessons learned through centuries of conventional wars will apply to nuclear war, and wonders whether or not the human capacity to cope with deception, surprise, and stress has improved over time. *What steps are available to minimize the risks that Beaumont describes?*

Rona explores the vulnerability of C^4 systems by considering a model in which stimuli are transformed by some logical "transform operator" into "effectors," the messages intended to modify the situation and generate some form of feedback. He argues that because his term "effectors" includes messages aimed at degrading an enemy's command and control process, C^4 should be considered as a form of combat in its own right. He also emphasizes the important role played by non-real-time (NRT) information flow, and points out

that such a flow exists (or needs to exist) at all levels of the hierarchy. He points out the need for each commander to exert effort to ensure the integrity of his own C^4 system, and concludes that highly automated systems are prone to catastrophic breakdowns at critical times. *What should a commander do to insure that the C^4 systems that support him do not fail when he needs them most? What can he do to stimulate the non-real-time information flow that Rona describes?*

The chapter from Joint Pub 6-0 assigned for this session attempts to define and describe global communications systems.

Readings

Required Readings

Carter, Ashton B. "The Command and Control of Nuclear War," *Scientific American*, January 1985, pp. 32-39.

Carter, Ashton B. "Assessing Command System Vulnerability," *Managing Nuclear Operations*, pp. 555-610.

Dougherty, Russell E. "The Psychological Climate of Nuclear Command," *Managing Nuclear Operations*, pp. 407-425.

Keegan, John. "The Validation of Nuclear Authority," from "Conclusion," *The Mask of Command*. New York: Viking, 1987, pp. 339-351.

Beaumont. Chapter 3, "Fighting Wars and Warfighting: $C^{2/3}$ in Nuclear Crisis and War."

Rona, T.P. "C^3 over the Past 3 to 5 Years—A Personal Learning Experience." Seattle, WA: Boeing Aerospace Co., undated.

Joint Pub 6-0. "Global C^4 Infrastructure," Chapter VI.

Supplementary Readings on C^4 Systems for Strategic Forces

Secretary of Defense. "Strategic Command, Control, and Communications," *Annual Report to the Congress*. [Describes programs intended to improve strategic C^4 systems. It may be

possible to infer current deficiencies from the descriptions of the improvements being made.]

Quester, George H. "Some Strategic Implications of Breakthroughs in C^3I," *Principles of Command and Control*, pp. 237-248 (1982). [Speculations about what the impact will be when more information is available to each side in future wars, and about whether more information favors the offense or defense, whether more information stabilizes or destabilizes the international balance, and whether more information makes the use of nuclear weapons more likely or less likely.]

Supplementary Readings on Survivability

Babbitt, Albert E. "Command Centers." *Managing Nuclear Operations*. pp. 322-351. [Babbitt describes in some detail the functions, organizations, and hardware of peacetime and wartime command centers. He outlines the special problems associated with trying to achieve survivability through mobility, and the technical challenge of trying to achieve information security on a multi-level basis. He concludes that command center survivability sufficient to support nuclear operations can be achieved at a cost of less that 10 or 15 percent of the cost of a major weapons system.]

Blair, Bruce G. "Strategic Command and Control and National Security, *Principles of Command and Control*, pp. 30-40 (1985). [Blair argues that funding for strategic C^4 systems has been neglected in U.S. defense budgets. He describes the vulnerabilities of U.S. strategic C^4 systems, and what the U.S. has done or failed to do about them. He then proposes some arms control measures designed to protect control systems and to reduce the risk of misperceptions.]

Blair, Bruce G. "Command Performance in the Mid-1980's," Chapter 6, *Strategic Command and Control: Redefining the Nuclear Threat*. Washington, DC: Brookings, 1985. pp. 182-211. [Blair, assessing the vulnerabilities of U.S. command systems designed to carry out the traditional strategy of responding to a first strike, argues that these vulnerabilities had been so great that U.S. C^4I

systems upgrades have really been aimed at solving those deficiencies rather than at overcoming the Soviet Union's purported advantage in being able to fight a protracted nuclear war. He describes the various C^4 systems that support strategic forces, as well as the attacks that those systems may have to absorb. His general thesis is that the state of C^4I is the primary determinant of overall strategic capabilities, but that this country's C^4I systems have probably never been capable of executing any of its declared nuclear strategies.]

Ford, Daniel. "Looking Glass," Chapter 5, *The Button: The Pentagon's Strategic Command and Control System*. New York: Simon and Schuster, 1985. pp. 147-167. [A journalistic examination of U.S. strategic C^4 systems. (Caspar Weinberger, then Secretary of Defense, criticized both the Blair and Ford books, alleging that they were full of inaccuracies and poorly founded judgments.) This chapter looks in detail at SAC's airborne command post, its capabilities and vulnerabilities, and the vulnerabilities of its communications links.]

Odom, William, "C^3I and Telecommunications at the Policy Level," in Coakley, pp. 109-113. [An "operator's" view in 1980 of the strategic communications problems that we then faced, and that then needed fixing.]

SESSION 9
C^4 System Architecture

A system is a collection of things working together to produce something greater.

Eberhardt Rechtin in *Systems Architecting*

If you look down the road, what you see is the pervasiveness of high bandwidth data communications and completely inexpensive computing power. If you combine those two things, there are many interesting things that you can do.

Paul G. Allen, *New York Times*, 31 March 92

What does he [Nicholas Negroponte] think is the most important tech trend of the future? The personalization of computer functions, he says. Within 10 years, Negroponte continues, computers will serve us as efficiently as a battalion of butlers. The trade-off: You'll have to reveal a lot about yourself to a machine. But, Negroponte says, the machine already knows it. One data base knows you've booked a trip to Canada. Another knows you bought a fishing reel you saw advertised in the back of Town & Country. Soon those data bases will talk to each other, and instead of junk mail addressed to "resident," you'll get subscription offers from Arctic Fishing magazine.

Maggie Topkis in *Financial World*

Focus

Having first studied the command and control *process*, and then having examined typical C^4 *systems*, we now consider how the architectures of such systems are organized to support the command and control process. In this session, we examine some of the issues related to the development of such architectures, including the role of the system architect.

C^4 System Architecture

Use of the term "architecture" when applied to C^4 systems is somewhat deceptive. We may all think we know what is meant, but we often have in mind the drawing of plans or the building of houses (or ships). For the purpose of this course, we will use the term "architecture" to mean the relationships established within a system designed to perform or support some function. In our case, we are concerned with the relationships within a C^4 system that supports the function of command and control. Note the obvious similarity between system architecture and the development of military plans for the organization and tasking of military forces. Here, the term "system architecture" will be understood to include:

- The clear identification of the system's subsystems,
- The allocation to subsystems of the subfunctions that need to be performed, and
- The establishment of the standards for interfaces between subsystems.

To appreciate the scope of military C^4 systems architecture it is necessary to visualize "measures of merit" at four distinct levels of effectiveness and performance:

- Warfare effectiveness
- C^2 functional effectiveness
- C^4 system performance
- C^4 equipment performance.

Warfare effectiveness, the top level—best established in combat on the battlefield, but during peacetime normally established by

various methods of analysis—represents a description of warfare capabilities found or considered necessary to accomplish military missions. Command and control functions need to be derived from such missions and may be couched in specific tactical terms or in broader operational terms.

The second level, C^2 functional effectiveness, represents the value that command and control contributes to warfare effectiveness, and consists of those command and control capabilities deemed necessary for the effectiveness of both the total warfare system and its other warfare component systems. This C^2 functional effectiveness is the starting point for a C^4 system architecture. A C^4 system architecture is the translation of the C^2 functions found essential at the second level into a description of an effective C^4 system (the third level). Given this description of the C^4 system, a C^4 system engineer can then develop a system engineering plan to organize individual C^4 equipments (the fourth level) into an effective system. Among the many system engineering issues to be resolved are: to what extent should an engineered C^4 system evolve into its ultimate capability, and to what extent should its full capability be achieved at the outset.

In order to relate—to "map"—the supporting C^4 systems (or their subsystems) to the command and control processes being supported, it is necessary first to visualize the command and control process for each commander, and then to make provisions for all parts of each process. To determine whether physical and electrical interfaces in the C^4 systems need to correspond exactly to the process interfaces in the command and control process, a system architect has to establish whether or not the C^4 system would be more effective if it were to be aligned with the corresponding process it supports, and to explore alternatives available to achieve this alignment.

In a time-flow sense, the command and control process for any commander can be subdivided into three parts:

- The process that leads up to the situation assessment (or information decision),
- The process that supports the making of operational decisions, and
- The process that triggers execution of operational decisions, and that monitors the progress of operations.

The first part of the process, which we will refer to as "information management," leads to a situation assessment. This first part consists largely of the movement, management, and manipulation of information on its way to the commander from sensors (and from subordinate forces). The Navy's COPERNICUS architecture is an example of an architecture that emphasizes this part of the command and control process. The second part of the process supports the making of operational decisions. A commander projects into the future what is known about the situation, and predicts the outcomes when each possible course of action is "gamed" against each possible enemy capability. This second part, which we will call "decision support," includes an assessment of each of the resulting outcomes. The operational decisions made at the beginning of the third part of the process are translated into directives communicated to executing commanders, who (among other things) make progress reports. This part of the process we will call "execution control."

During this course, we have stressed that a C^4 systems is developed for the support of a command and control process. Yet, the prior existence of C^4 systems can sometimes reverse this relationship, which is what happens when the command and control process of a commander has to be shaped to fit an already existing C^4 system. For example, within a navy battle group, some command and control functions are assigned to commanders or commanding officers only when their C^4 systems already include a naval tactical data system and a special intelligence capability.

Failures in the functioning of systems can often be attributed to an unwise allocation of functions to subsystems, or to some mismatches at interfaces between subsystems. The architecture of a C^4 system is analogous to the architectures of highway systems, hospitals, or telephone systems. Each system is made up of subsystems, and the total system can be characterized as a network of "nodes" and "links." Some of the common architectural issues for C^4 systems are:

- Whether the capabilities of circuits or computers are to be dedicated only to certain users, or whether the system will be a "common user" system;
- Whether data and information are accessible only to certain commanders, or are accessible by all commanders; and

- Whether the overall system is controlled centrally, or operates in a "self-correcting" decentralized manner.

Modern technologies open up new possibilities, new ways to exercise command and control, by making possible what was previously too costly, too difficult, or impossible. The marriage of computer and telecommunications technologies has created the opportunity for direct information exchange between computers at great distances. This interconnection of distant computers through telecommunications systems illustrates some of the major features of C^4 system architectures. The evolution of such distributed information systems using equipments of different design and manufacture is now made possible when such systems have been subdivided and when effective interface standards have been applied between the subdivisions. These interface standards make it possible to modify one portion of the total system without doing violence to other portions. The International Organization for Standardization (ISO) has established a framework that is now the basis for a new generation of standards for the design, development, and evolution of distributed information systems. A general understanding of this framework also provides an appreciation for the number of functions that need to be performed to achieve computer-to-computer connections.

This new architecture is called Open Systems Interconnection (OSI). The architecture achieves its purpose by separating the functions performed in an end-to-end (computer-to-computer) connection into seven clearly identified "layers." This OSI modular framework identifies the functions that need to be performed at each layer in order to accomplish the transfer of data between application processes at separate locations. The OSI establishes the standards for the *interfaces* between adjacent layers and for the *protocols* at each layer between connected users. Vendors have retained the flexibility to incorporate new and improved technologies within each layer, provided only that their equipment adheres to the prescribed interface standards between adjoining layers and can execute the protocols with the same layers at the distant end.

Each of the seven layers performs specific functions and provides specific services to adjacent layers. The upper three layers deal with the form of the information itself, insuring that the information reaching the destination is meaningful and can be processed there. The lower three layers deal with the transmission of information, by

establishing the "bit pipe" for its transfer. The middle layer (the Transport Layer) provides the "user's liaison" between the upper three layers that format the information and the telecommunications services of the three lower layers, and also monitors the communicating processes to insure that they provide a consistent quality of service.

The principal function of each layer is listed below:

- Application Layer: interface between the users and the process;
- Presentation Layer: control of the encoding and decoding of information being transferred;
- Session Layer: management of an orderly communications dialogue between users;
- Transport Layer: provision of the appropriate quality of telecommunications service to support reliable transfer of information between users;
- Network Layer: routing of transmission paths through a telecommunication network;
- Data Link Layer: reliable transfer of bits of information over physical circuits;
- Physical Layer: activation, maintenance, and deactivation of physical circuits.

A seldom appreciated fact about C^4 systems is that they do not as complete systems really exist. The capabilities we refer to rather loosely as provided by C^4 systems are actually provided by bringing together two interconnecting but different kinds of systems: telecommunications systems on the one hand and what are often called command and control systems (but which, to avoid confusion, in this course are called "command center" systems) on the other. In the OSI model, functions at the upper levels are performed by command center systems, while the lower level functions are performed by telecommunications systems.

A few military systems have been built as complete C^4 systems that, in effect, contain the functions of all seven layers. One such system was the Naval Tactical Data System (NTDS), which includes computers that act as sources and destinations of data transfer and, initially, at least, included its own dedicated transmitters, receivers, and antennas. Although the Joint Tactical Information Distribution

System (JTIDS) was generally expected to replace NTDS, it would have initially replaced only its transmission layers as well as provide a display for aircraft, but the need for much of the upper level processing now performed by NTDS would have remained. The OSI is a useful framework to remind us of *all* the functions that need to be performed in a distributed information system.

For their part, the planners and designers of command center systems assume that suitable telecommunications service will be provided, while planners and designers of telecommunications systems expect that, increasingly, the "loading" they need to carry will be in the form of transmissions between command center systems, rather than transmissions of narrative messages. The higher "speed" of computers is now one of the dominant factors that generate requirements for telecommunications, the other being the availability and improving quality of imagery.

Telecommunications systems usually function under the "operational control," "authoritative control," or "authority necessary to ensure effective operation" of some commander or agency who insures that telecommunications service is provided and that any casualties will be promptly restored. For computer systems, the identification of similar authorities to insure that interconnected command centers will function effectively has so far been slower to develop.

Commentary on the Case Study and the Readings

The guidance for the restructuring of the U.S. Navy's command and control, communications and computers, and intelligence (C^4I) systems has been issued in the document *Copernicus Architecture*. The chapters assigned for reading are those on the architecture's "concept" and its "building blocks." Whether or not the Copernicus architecture is seen as fulfilling the requirements for a complete C^4 system architecture, it can be viewed at least as an architecture for the flow and management of sensor information. One of its appealing features is that instead of the expectation that information will be *pushed* through the system by information gatherers, there is more emphasis on commanders' ability to *pull* information from the system. For this course, Copernicus is presented as an example concept of a system architecture and an illustration of how challenging it is to articulate an architecture that is at once:

operationally responsive, technically correct, and clear. The seminar discussion of Copernicus will focus on these three aspects of this architecture as written, and on any considerations of command and control and of jointness that may be missing. *What changes to the written architecture would you propose?*

McKnight makes a plea to system architects to design systems with people in mind: both decision makers and staff officers. He seems to be saying that we attempt too much, and ought to discipline our processes more. *Do you agree?*

Mayk and Rubin have collected for comparison fifteen different paradigms of C^4 systems (their collection may not be exhaustive). Students should come to this session prepared to select the paradigm that best represents the essential elements and relationships in a C^4 system. Students may select a paradigm from the reading, adapt one, or introduce an entirely new one. The last several pages of the Mayk and Rubin reading contain a description of the Open Systems Interconnection framework and a proposal for a seven-layer reference model just for C^4. *Does their proposal make sense to you?*

As a contrast to U.S. system architectures, the Beaumont reading describes the Soviet approach to command and control, from which their system architectures might be inferred. While he describes the many similarities with Western concepts (including concern about the tension between centralized control and local autonomy), he also stresses the Soviet emphasis on speed, quantification, and psychology. *Are there advantages in such an approach over ours?*

Vineberg and Warner propose a generic architecture for C^4 systems, and they identify the characteristics that they suggest be applied as quality requirements. Their network architecture is based on the ISO seven-level architecture. A seven-level database management architecture is also proposed. The nodes and links would be physically configured to reflect the geographic distribution of command functions. *What would be the advantages and disadvantages of such a generic architecture for future systems?*

The chapter from Joint Pub 6-0 lays out the responsibilities of various officials and commanders for the employment of C^4 systems and describes the methods by which C^4 systems standardization is achieved. *Would this pub be useful to you on the staff of a newly appointed joint task force commander?*

Readings

Case Study

Copernicus Project Office. "The Copernicus Concept" and "Building Blocks of the Copernicus Architecture," Chapters 3 and 8, *The Copernicus Architecture, Phase I: Requirements Definition.* Washington, DC, August 1991.

Required Readings

McKnight, Clarence E. Jr., "C^3I Systems at the Joint Level," in Coakley, pp. 57-58 (1986).

Mayk, Israel and Rubin, Izahak. "Paradigms for Understanding C^3, Anyone?" *Proceedings of the 1987 Command and Control Research Symposium*, pp. 93-103, and *Science of Command and Control*, pp. 48-61.

Beaumont. Chapter 4, "Through Many Glasses Darkly: Soviet Command and Control."

Vineberg, M. and Warner, C. "A Generic Command Support System," *Proceedings of the Fifth MIT/ONR Workshop on C^3 Systems*, Cambridge, MA: MIT, 1982.

Joint Pub 6-0. "C^4 Systems Employment Responsibilities" and "Joint and Combined C^4 Systems Standardization and Procedures." Chapters IV and V.

Supplementary Readings on C^4 System Architecture

Wriston, Walter B. "The Great Equalizer," Chapter 9, *The Twilight of Sovereignty: How the Information Revolution is Transforming Our World.* New York: Scribner's, 1992. pp. 153-169. [In a book devoted to the impact of the technologies of telecommunications and computers ("the new electronic infrastructure") on the worlds of finance and international politics, there appears this chapter about some of the measures that have in the past been taken to protect (or to penetrate) information in transit, and some of the

measures available today. The general thesis of the book is that power is at last "really moving to the people."]

Strassmann, Paul A. "Corporate Information Management Streamlining: A Cottage Industry." *Defense 91*, November-December 1991, pp. 18-20. [Strassmann describes the Corporate Information Management (CIM) initiative which he was then in charge of as Director of Defense Information in the Office of the Secretary of Defense. He outlines a series of initiatives to achieve a cumulative saving of $35 billion in DOD information systems by the end of Fiscal Year 1997. The initiatives include improving software development and acquisition, increasing the reuse of software, standardizing interfaces in information systems, and standardizing the software "tools" used for information systems. He visualizes a future where computing power is considered just another utility, paid for by users on a fee-for-service basis.]

Kuhn, D. Richard "IEEE's Posix: Making Progress," *IEEE Spectrum*, December 1991, pp. 36-38. [Describes the standardization efforts being made so that application software can become portable from workstation to workstation. An "open systems" environment for computers will be achieved by the establishment of a standard interface between applications software and the software of operating systems. Posix is an acronym based on the initials of "portable operating system interface" with the addition of the letter "X' from Unix, the operating system. This description of efforts to identify and develop interface standards is a useful reminder of the complexities of achieving standardization in computers.]

Rechtin, Eberhardt. *Systems Architecting: Creating and Building Complex Systems*. Englewood Cliffs, NJ: Prentice Hall, 1991. [The text for a pioneering course in system architecture at the University of Southern California, written by a practitioner who had been director of deep-space telecommunications and radio-navigation systems, who had as Assistant Secretary of Defense (Telecommunications) made important architectural decisions to facilitate the emergence of secure voice systems and tactical satellite communications systems, and had later been president of Aerospace Corporation. Drawing primarily on examples from

systems in the telecommunications and aerospace world, Rechtin describes how architectures for complex systems are developed, what special challenges are faced by system architects, and how system architects relate to managers, to users, to systems engineers, and to system builders. He emphasizes the problems of *complex* systems, and distinguishes between system architecting and system engineering by pointing out that system architectures are function-based while system engineering is primarily involved with integration. This practical book includes some "big picture" insights in the form of heuristics (some of them been used in this course as epigraphs).]

Beaumont, Roger. "Nelson's Telescope: The Problems of Tension in C^2 Systems" in *Naval Command and Control: Policy, Programs, People & Issues.* Fairfax, VA: AFCEA International Press, 1991, pp. 60-68. [The "tension" of Beaumont's subtitle is that between echelons in the chain of command, the tension between hierarchy and function. He cites examples of this tension from history and suggests that fresh consideration be given to the use of military history as a basis for doctrine, training, and sensitization. The basic issue that Beaumont raises is whether or not these "vertical" tensions need to be taken seriously into account in the development of supporting systems.]

Allard, C. Kenneth. "Building Joint Approaches: Of JINTACCS and JTIDS," Chapter 7, *Command, Control, and the Common Defense.* New Haven, CT: Yale University Press, 1990. [Here Allard takes up the case of JTIDS (Joint Tactical Information Distribution System), and notes that differing preferences as to whether control of aircraft should be by digital or voice methods became a factor in the contention between the Air Force and the Navy on this project. He draws from the JTIDS story several conclusions: acquisition is a complex process, there seems to remain skepticism about pursuing commonality, there was not enough strategic planning of architectures for total systems by the Services, each Service focuses on its own operational environments and preferred weapons systems, and JTIDS in the end proved both too expensive (in dollar terms) and too disruptive of contemporary practice.]

Beam, Walter R. *Command, Control, and Communications Systems Engineering*. New York: McGraw-Hill, 1989. [Written as a textbook: a technical treatise on the technologies and the systems engineering considerations that need to be accommodated in the design and integration of C^3 systems.]

Holley, I.B. Jr. "Command, Control and Technology," *Defense Analysis*, Vol. 4, No. 3, pp. 267-286, September 1988. [Holley considers the generic problem for military commanders to be one of adopting technological advances without losing their command authority or freedom of action. He examines the influence that technological developments have exerted on command and control, and finds that these influences are not always positive. His review of the history of command and control differs somewhat from van Creveld's and Rechtin's, and emphasizes still other developments like advances in cartography and the German V-2 rocket during World War II.]

Beam, Walter R. "A View of Military Command, Control and Communications Systems of the Future," *Principles of Command and Control*, pp. 427-438 (1987). [Some of the technological clues to future C^4 systems: the possibilities of artificial intelligence, increased computing power, remotely operated systems, high-resolution sensors, more accurate determination of time, and higher quality information. Beam raises the issue of whether technological dividends ought to be spent on higher performance or on higher reliability.]

Kroening, Donald W. "Army Command and Control Information Systems Requirements Definition," *Principles of Command and Control*, pp. 84-94 (1986). [Describes the difficulties in defining the requirements for C^4 systems, in this case for the U.S. Army, and in acquiring new systems in a timely manner.]

Latham, Donald C. and Israel, David R. "A Modular Building Block Architecture," *Principles of Command and Control*, pp. 117-132 (1986). [Describes the Modular Building Block (MBB) architecture for C^4 systems, a standardized approach to the packaging and interconnection of C^4 systems that is intended to

allow the configuration or replacement of individual cabinets of equipment relatively quickly.]

Welch, David J. "Evolutionary Development of Command and Control Systems: The Fort Lewis Experience," *Principles of Command and Control*, pp. 133-141 (1986). [Describes the evolutionary development by the Army of a distributed command and control system, using off-the-shelf components, and concludes that an evolutionary approach to the development of such systems is much better than that achieved from an *a priori* specification of the ultimate system, even though evolutionary development is at odds with quality control and configuration management practices.]

Foss, Ronald W. "Processing Environments for Dispersed Command and Control," *Principles of Command and Con ol*, pp. 370-381 (1986). [Some concepts to be considered during the development of transportable computer-aided command centers for tactical commanders: the use of functionally modular C^4 facilities with an emphasis on virtual processing environments instead of on the physical modules for each function; decoupling mission software from its underlying hardware; and using common system software as the interface between functions.]

Campen, Alan D. "Force and Force Control—In Pursuit of Balance," *Principles of Command and Control*, pp. 397-406 (1986). [Urges that operational commanders involve themselves in the requirements generation process.]

Collard, Keith. "Systems Engineering and Integration in the U. S. Navy," *Principles of Command and Control*, pp. 142-155 (1985). [Describes how the Navy was approaching the challenge of engineering and integrating C^4 systems, suggesting (without proof) that every dollar spent effectively "up front" will save possibly a hundred dollars in the long run.]

Freck, Peter G. "The Role of Manned Simulator Test Beds in Evolutionary Acquisition of C^3I Systems," *Principles of Command and Control*, pp. 156-164 (1983). [Describes how manned simulator test beds could be used during the evolutionary

acquisition of C^4 systems, pointing out their usefulness in supporting mission-oriented evaluations undertaken to determine operational utility. Freck concludes that most test beds are not being used to assist in the acquisition process, but should be, and suggests that what is needed is "centralized coordination and decentralized execution," meaning, presumably, that someone ought to take charge of all the test beds.]

Skantze, Lawrence A. "Project Forecast II—A Glimpse at Tomorrow's C^3I," *Principles of Command and Control*, pp. 439-451 (1982). [A U.S. Air Force project to identify those military technologies that hold the most promise for exploitation over the next twenty years. Skantze reviews the impact on C^4 systems expected to be caused by continuing progress in such technologies as artificial intelligence, photonics, acoustic charge transport devices, software, and microelectronics.]

Jacobs, J.F. *Design Approach for Command and Control*. SR-102. Bedford, MA: MITRE, 1964. [A timeless piece written in 1964 to engineers and system designers explaining what they should understand about the command and control process that will be supported by the systems they will be called upon to design and build. He uses a few simple but powerful examples to illustrate what is supposed to happen in the command and control process, and then describes the elements and the phases of the design process. Jacobs' explanation provides an insight into how an experienced systems engineer views the command and control process, as well as how he thinks engineers and designers ought to approach the problem of creating a C^4 system. He insists that such systems should not be considered as existing apart from the humans involved, and he emphasizes that command and control is concerned primarily with the communication of (command) concepts. He characterizes such communications as involving translation (of the concepts into some shared symbols), embedding (of the communicated concepts into the universe of already shared concepts), and maintenance (of the communicated concepts to prevent their subsequent modification).]

SESSION 10
Evaluation of C^4 Systems

It's very hard to quantify the benefit you get by spending a million dollars on a command, control and communications system.... The system analyst can do marvels with the tank—probability of kill, first sighting; add a laser or a laser designator to it and the probability of kill goes up to a measurable degree. It's harder, though, to quantify the benefits if you add another radar which gives you a second way to identify a Soviet missile and decide that it is indeed aimed at you. People who deal with C^3I systems analysis and cost benefit studies would be much happier if they had some way to do that.

Lee Paschall (1980), quoted in
C^3I: Issues of Command and Control

Focus

In this final session, we try to come to grips with a pair of ultimate questions about effectiveness: how can we evaluate the effectiveness of C^4 systems? and how can we weigh the utility of C^4 systems against the utility of other contributors to combat effectiveness? We then synthesize and conclude the course.

Evaluation of C^4 Systems

There are two ultimate problems for architects and engineers of C^4 systems:

- To establish the extent to which their C^4 systems will support the effective command and control of combat operations, and
- To answer the cost-effectiveness question: whether investment in a more capable C^4 system would result in more combat effectiveness than an equal investment in alternatives, including the fighting forces themselves.

Unless a C^4 system is evaluated during actual combat, it is impossible to know for sure how well or poorly it will perform under such conditions. Yet some failures of C^4 systems even under combat conditions might be attributable to the way they have been used. After all, C^4 systems provide support to the command and control processes (and individual command styles) of commanders functioning in command structures designed to support a wide variety of possible missions and tasks. Nevertheless, it should be possible prior to the ultimate test of combat to identify at least the *characteristics* of a C^4 system that are expected to make a difference.

Several approaches might be employed in an attempt to resolve questions about the effectiveness of C^4 systems. One would be to study recent combat or crisis experience very thoroughly in order to establish what contribution was made by individual C^4 systems or what penalties would have resulted without those systems. There are some drawbacks to this approach: detailed information necessary for such a study is usually classified and may not be generally available. Furthermore, telecommunications and computer technologies are developing so fast that it could be argued that "system" lessons learned from one situation might be less relevant to later situations supported by systems that would have incorporated better technologies. A second approach to establishing effectiveness of C^4 systems would be to develop models of the C^4 systems under consideration so that the performance values could be manipulated to replicate and reflect improvements, even planned improvements. The readings for this session will offer some thoughts on both of these approaches.

As a framework for thinking about the several kinds of analysis that might be accomplished, we will revisit the four levels of effectiveness and performance postulated in the previous session:

- Warfare effectiveness

- C^2 functional effectiveness
- C^4 system performance
- C^4 equipment performance.

Starting this time at the fourth (or lowest) level, network models are available to translate the measured (or postulated) performance of individual equipments into estimates of the performance of a large C^4 system engineered for optimum performance. This sort of modelling and analysis is well within the abilities of modern C^4 system engineering.

To characterize the relationships between system performance and functional effectiveness (between the third level and the second level), the C^4 system architect could develop a model whose inputs are the parameters of C^4 system performance and whose outputs are measures (or estimates) of the performance of C^2 functions deemed essential for warfare. Such a model might also incorporate an estimate of the contribution that command and control might make to the other (warfare or support) models also at the second level. Modelling the transition from system performance to functional effectiveness has generally been attempted in the opposite direction—from desired functional effectiveness to required system performance—but without much rigor.

The relationship between the second level (C^2 functional effectiveness) and the top level (warfare effectiveness) requires primarily a model of *warfare*, not a model of C^2. Such a warfare model is needed to answer the top-level cost-effectiveness question, but combat and theater-level analyses now used to construct warfare models are notoriously deficient in their representation of the dynamics of command and control.

In summary, it is easiest to model how well C^4 equipments will perform together as a C^4 system; it is more difficult to model how well a C^4 system will support the command and control functions, but occasionally worth the effort. Most difficult of all seems to be the modelling of the contribution of command and control to warfare effectiveness. To understand the extent of this contribution appears to require both combat theory and C^2 theory in order to model the command functions usually missing from warfare modelling and analysis.

While the framework described above recognizes performance and effectiveness at different levels of system integration, it fails to

provide for several other dimensions: the level (whether strategic, operational, or tactical) of the commander and the level of warfare (along a spectrum of violence). Finally, the scope of each analysis may be limited by the types of measurements or observations that are possible to make, by the measure of effectiveness that will provide insight, and by the need to draw conclusions that are both supportable and relevant.

Commentary on the Readings

Van Creveld declares that the history of command has been an endless quest for certainty, resulting in a race between the demand for information and the ability of command systems to meet that demand, a race he believes is not being won by command system designers. He points out that the amount of uncertainty to be resolved depends both on the nature of the task to be performed and on the structure of the command organization itself. When less information is available than is needed to carry out a task effectively, an organization can attempt:

- To generate and process more nformation,
- To restructure itself so that it can function effectively on less information, or
- To restructure the task into parts that can be dealt with separately on a semi-independent basis.

Noting that in war, confusion and waste are inevitable, van Creveld is convinced that of these three options, the third (restructuring tasks into parts) will remain superior to the other two. He is also convinced that commanders should actively seek information by using their own independent means: directed telescopes. *Are van Creveld's preferences for semi-independent tasks and for directed telescopes consistent with each other?*

One of van Creveld's key ideas is that the choice between centralization and decentralization is really a decision about the distribution of uncertainty through a hierarchy. He assumes that reducing uncertainty anywhere will increase it somewhere else: thus, centralization reduces uncertainty at the top but increases it at the bottom, while decentralization has the opposite effect. It is human nature for each of us to want to eliminate (or at least reduce)

uncertainty at the level where we happen to be, so it is understandable that decision makers at higher levels will demand that *their* uncertainty be reduced, driving C^4 systems toward centralization. He believes, however, that decentralization is superior to centralization, and there *have* been commanders (such as Nimitz) who accepted a level of uncertainty during action in the interest of better results at the scene of action. *What would be the practical consequences of more decentralization? How could it be achieved?*

General Edge sees command and control challenges as being as being as operational as they are technical. He distinguishes "determinate" C^4 systems that provide real-time control over weapons systems from other C^4 systems used for planning and resource management. He, too, sees a C^4 system as consisting of standard operating procedures, people that execute the procedures, and facilities that support that execution. *Would you agree with him that we should use "gateways" to resolve interoperability problems, and that electronic warfare can be expected to become more centralized?*

Everett takes on the ultimate task—evaluating the worth of command and control—by applying Lanchester's linear and square laws to a simple combat situation. He uses the Lanchester models to calculate the utility of: being less uncertain about an enemy's forces than the enemy is about ours, having more timely information than is available to an enemy, and being more mobile than the enemy. *Do Everett's calculations justify his conclusions? Do these characteristics—reduction of uncertainty, timeliness of information, and ability to employ the mobility of forces—constitute the major contributions of command and control?*

Because Everett feels that it is quite unrealistic to assume perfect C^4 in real life, he suggests the introduction of random errors and delays into wargames. *How would you introduce errors and delays? What would you accomplish by doing so?*

Dockery suggests that fuzzy set theory be considered as a framework for understanding measures of effectiveness. *Does fuzzy set theory show any promise of being useful in understanding or explaining command and control?*

Beaumont lists in his Chapter 5 some paradoxes of command and control that emphasize his three themes:

- It is not clear how well (or badly) C^4 systems will function under attack;

- The sophistication of hardware and software is not matched with a corresponding sophistication in the selection and training of system operators (nor are systems being designed to match the abilities of operators to use them); and
- People may remain unaware that machines are taking over, until they have succeeded in doing so.

What might be done to determine how C^4 systems will function under attack? Must greater sophistication in systems be matched with corresponding sophistication in operators, or would simplification be a better answer? Is there any evidence that the machines are really taking over?

In his final chapter on the use of space, particularly for the Strategic Defense Initiative (SDI), Beaumont argues that coherent system design will be imperative in space, but coherence has hardly been achieved in terrestrial systems. He wonders what role (if any) humans will play in the future, and he speculates that the momentum of C^4 systems has already pushed them beyond human mastery. *Is the achievement of coherence in C^4 systems really possible? How is coherence normally achieved? Are his concerns about the declining role of humans justified?*

General Welch laments the lack of progress in the ability of analysts to assess C^4 systems. He discusses the shortcomings of the assumption (derived from economics theory) that people will behave in a rational manner, and concludes that it is still not clear how real-world commanders behave. He criticizes the narrowness of analyses that examine only one part of a C^4 system, but concedes that good C^4 models are lacking. Noting that all parts of C^4 systems seem to be evolving, he finds that concepts of combat also are evolving. He urges that assessments of a C^4 system consider its flexibility as well as its effectiveness. He argues for the need to distinguish between three different measures—measures of performance, measures of C^4 effectiveness, and measures of force effectiveness. *Are these distinctions consistent with the four levels of performance listed earlier in this chapter?*

Gustavson (writing in 1979) surveys the development of command and control, and the evolution in our thinking about command and control. He asserts that one underemphasized purpose of command and control is to diagnose what is happening, even if

unexpected, and developing appropriate strategies and tactics. He then outlines an imaginary war that begins gradually sometime in the future. He poses questions that might arise at the strategic and theater levels. He concludes with five recommendations, including one to develop a more comprehensive framework for understanding the contributions and limitations of command and control. *Have you found much progress during the past decade in implementing these recommendations? Are Gustavson's recommendations still valid and relevant today?*

Conclusion

We began this course with a reminder of the nature of the military enterprise—combat—accompanied by friction and the fog of war. We explored the several kinds of decisions associated with command and control. We then considered the command and control process in the wars and crises of history. Finally we examined some of the C^4 systems of today and tomorrow.

Certain themes that have recurred through the course include:

- There is a distinction between the *process* of command and control and the *systems* that support it.
- The command and control process—which consists of developing situation assessments, making operational decisions, establishing organizations—is characterized by the timely reduction of uncertainty.
- The making of information decisions normally requires a network of information flow from sensors and reporting commanders through a process of correlation, filtering, and analysis that converts data into information and information into operationally useful knowledge relevant to mission accomplishment.
- Although some information may reach commanders without any need for them to seek it, they should anticipate their information requirements: first by analyzing the types of decisions they expect to make, then by identifying the information they would use to make such decisions, and finally by requesting or collecting that information, perhaps by the use of "directed telescopes."

- Commanders should at least attempt to influence the agencies or centers that correlate, filter, and analyze information en route to them by encouraging fusion centers to perform those functions with a keen sense of commanders' perspectives and needs and to generate information relevant and in a form that can readily be assimilated.
- While some commanders may starve for information, others may be drowning in it, and the likelihood of the latter situation prevailing is expected to increase, underlining the importance of eliminating irrelevant information.
- Warfare is at least a two-sided problem, and outcomes depend on decisions made by commanders at several echelons on both (or all) sides.
- Although reduction of uncertainty is an objective of most parts of the command and control process, the utility of uncertainty reduction is ultimately limited by the two-sided nature of combat and the stochastic pattern of combat outcomes.
- It is possible to become the victim of hidden or unstated assumptions about the nature of the current situation or about the course of future events.
- Each organization can be characterized as being located along a centralization/decentralization dimension; the extent to which that authority is centralized or decentralized is likely to affect the way that command is exercised, the nature of the command and control process, and the allocation of assets to C^4 systems.
- The command and control process relies on the shared understanding of separated commanders, an understanding that can be enhanced by common doctrine, a spirit of teamwork, and an *early* and *continuous* exchange of information.
- While the command and control process at each node is closely related to the military planning process, the command and control process overall could be characterized as a web of human relationships and shared understandings.
- Commanders are *part* of C^4 systems, not just users of them.
- Matching a commander's command "style" with a C^4 system could in theory be accomplished by modifying either the

style or the system, but is probably best accomplished by modifying both.

- A C^4 system can be expected to reflect some underlying command philosophy.
- One objective of C^4 systems is the reduction of the time required for the accomplishment of each of the steps in the command and control process.
- *Timeliness* is a characteristic of information, but *time* is a commodity to be apportioned to the series of events from initial decision to the taking of action. Because there is only a finite amount of time—("critical time") from event to a useful reaction to it—for the total command and control process to function, commanders should consider the conscious allocation of time to the successive parts of that process.
- Reliance on sophisticated C^4 systems and new technologies (because they offer increased capabilities) may create some new and unprovided for risks and vulnerabilities that need to be recognized and understood.
- As it becomes clearer that the exercise of command is heavily dependent on C^4 systems, it will become increasingly attractive to an enemy to make such systems prime targets for exploitation, manipulation, or destruction.
- A C^4 system may be evaluated using four types of criteria:

  - the performance of its subsystems,
  - its performance as a total system,
  - its contributions to the exercise of command, and
  - its contribution to the success of military operations.

Readings

Required Readings

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effectively the new technologies and how to absorb a new (joint) paradigm for combat. He notes with some discouragement that the absorption of new technologies sometimes takes a generation and feels that the writing of new joint doctrine may prove futile without joint exercises, joint training, joint readiness tests, and actual joint operations, all of which he recommends.]

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Acronyms

CINCSAC	Commander-in-Chief, US Strategic Air Command
CINCSPACE	Commander-in-Chief, US Space Command
COMINT	communications intelligence
DOD	Department of Defense
EW	electronic warfare
EXCOM	executive committee
ISO	International Organization for Standardization (ISO)
JCS	Joint Chiefs of Staff
JTIDS	Joint Tactical Information Distribution System
JOPES	Joint Operation Planning and Execution System
NRT	non-real-time
NSC	National Security Council
NTDS	Naval Tactical Data System
OPSEC	operational security
OSI	Open Systems Interconnection
SDI	Strategic Defense Initiative
SHF	super high frequency
SHOR	Stimulus-Hypothesis-Option-Response
TADIL	tactical digital information link
VLF	very low frequency